PPSP-V-82-1

Vienna Fly Ash Disposal Site
PROBLEM DEFINITION STUDY

Final Report

Submitted to

Maryland Department of Natural Resources
Power Plant Siting Program
Tawes State Office Bldg. (B-3)
Annapolis, Maryland 21401

7 June 1982

Submitted by

Environmental Resources Management, Inc.
999 West Chester Pike
P.O. Box 357
West Chester, Pennsylvania 19380

MARYLAND POWER PLANT SITING PROGRAM

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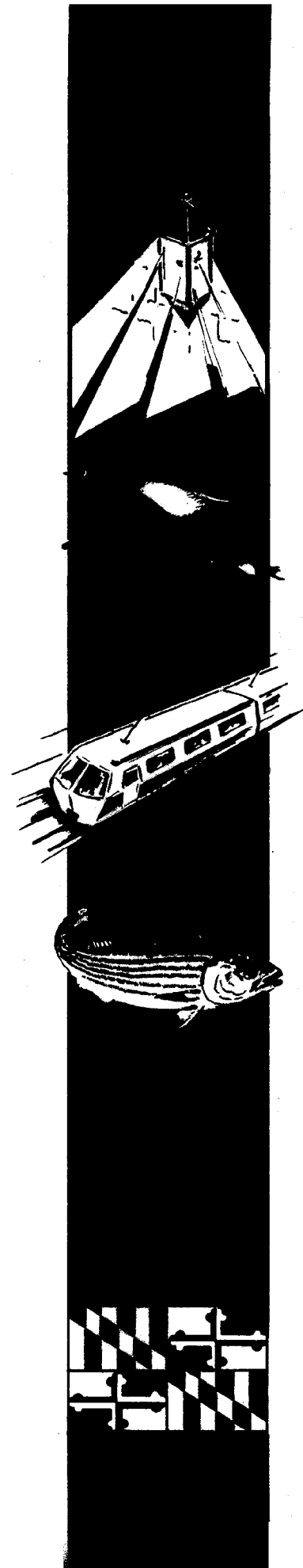Annapolis, Maryland 21401

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SECTION I

INTRODUCTION

A. Background

This study was undertaken to determine if environmental
contamination resulted from the disposal of fly ash in a
diked disposal area. The now unused disposal area is adja-
cent to the east side of the Nanticoke River at Vienna,
Maryland, in Wicomico County, starting about 400 feet north
of U.S. Route 50 (Figure 1). The study was conducted for
MD-DNR's Power Plant Siting Program by ERM, Inc., the Pro-
gram's Solid Waste Studies Integrator, as part of a gener-
alized interest on the part of the state in power plant
solid waste issues.

B. Disposal History

From 1950 to 1972, Delmarva Power & Light (DP & L) operated
a series of small ($\leq$ 70 MW) coal-fired generating units at
their Vienna Power Station. The resultant fly ash/bottom
ash from these units was first flushed into settling basins
near the plant, then, from 1966 to 1972, the finer fly ash
was sluiced across (under) the Nanticoke River to a diked
disposal area of about 100 acres of wetland habitat adjacent
to the river. This disposal site was neither lined nor
covered, in conformance with standard industry practice at
the time. The fly ash slurry covered about 80 percent of
the disposal area when use of the site was discontinued in
1972. Water overflow was provided by two pipes through the
dike in the northeastern corner of the site.

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Figure 1
Vienna Site Assessment Location
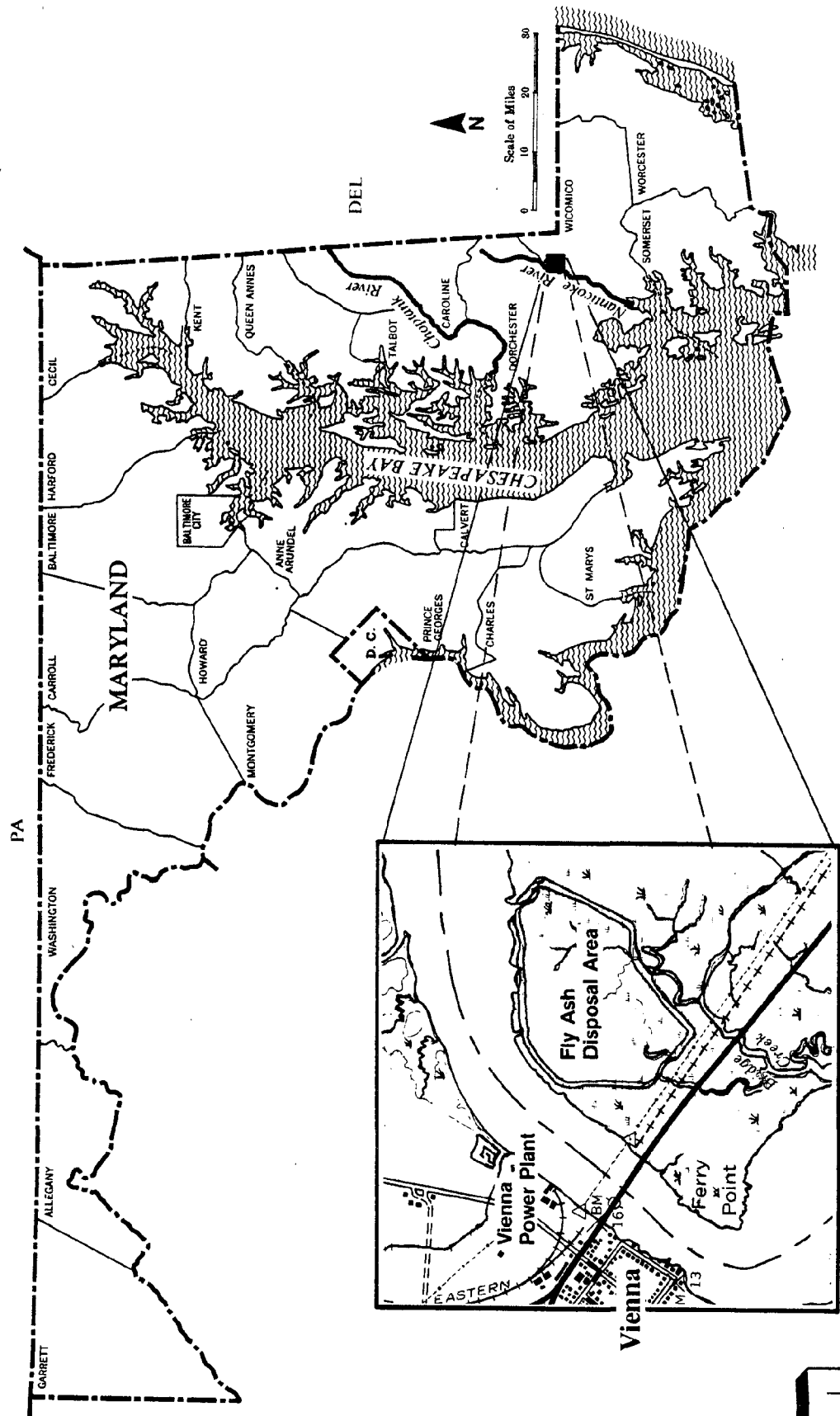
The dike has since been breached at several locations per-
mitting tidal flushing, rapid runoff, and flooding of the
site during periods of high river flow. The area covered
with ash has gradually revegetated since the phased conver-
sion of the Vienna plant to oil in 1972.

The Nanticoke River is an important spawning and nursery
area for several commercially important fishes, especially
striped bass. The surrounding marshes are frequented by
migratory waterfowl and shore birds for feeding, resting,
and nesting. The Town of Vienna and a food processing plant
have given consideration to using the surficial aquifer for
process and drinking water. However, recent investigations
of the aquatic biota near the Vienna disposal site (Mehrle
et al., 1982) have indicated possible arsenic and selenium
contamination problems. The current lack of containment of
the ash material, the recognition of ash as a potential
source of trace metal contamination, and the proximity of
the disposal site to both ground water and surface water
supplies necessitated an assessment of the potential envi-
ronmental impacts of the ash, its leachate, and present
physical and biotic conditions.

C. Study Objectives

The study objectives addressed the potential areas of impact
resulting from the disposal of fly ash at the Vienna site.
The study investigated the following objectives:

   1.   determine if fly ash-derived contaminants
        have affected surface and ground water qual-
        ity in the surficial aquifer;

2. determine if the aquatic and terrestrial biota
    populating the disposal site and the surround-
    ing area have been affected by fly ash-derived
    contaminants;

3. assess the implications of the above-mentioned
    effects on the health of the surrounding human
    population which utilize these resources.

SECTION II

BACKGROUND

A. Fly Ash Review

The burning of coal in power plants produces large quanti-
ties of fly ash. This ash is removed (cleaned) from the
stack gases by either dry or wet methods. If wet methods
are employed, the ash usually ends up in a slurry form re-
quiring disposal in a solid waste facility. Bottom ash from
the furnaces is often combined with this slurry. The Vienna
power plant used a wet ash collection system and disposed of
the ash in an unlined, diked disposal area in a tidal marsh,
in accordance with acceptable disposal practices at the
time.

As stated in a 1979 EPRI report by GAI Consultants, Inc.:

> "Fly ash is comprised of very fine particles, the
> majority of which are glassy spheres, scoria, iron
> rich fractions, and some crystalline matter and
> carbon. Due to its size and shape, the charac-
> eristics of fly ash are that of a high surface area
> to volume ratio solid that has agglomerated mate-
> rials on its surface. In general, the composition of
> the spherical portion of the fly ash is somewhat
> immune to dissolution due to its glassy structure.
> However, on the surface of the spheres exists either
> easily exchangeable or adsorbed molecules which,
> when in the presence of a liquid, become dissolved.
> It is this mechanism, some researchers believe,

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which ultimately produces leachate (Theis and Richter, 1979). Some of the very minute spheres may also dissolve into solution and contribute to the leachate. The elemental composition of the structure and surface material is then a function of not only the feed coal, but also the combustion sequence and method of collection."

The elements selected for investigation in this study were aluminum (Al), arsenic (As), chromium (Cr), and selenium (Se). Aluminum was chosen due to its high abundance in ash (a tracer), while the other three elements were selected because of their toxicities and potential for bioconcentration. A discussion of their potential toxicities follows in the next section. These and other trace elements have a wide range of concentration levels in fly ash as shown in Table 1. These metals chosen are also on the U.S. EPA list of priority pollutants.

Leachate from ash disposal sites is of concern due to the possibility that metals and ionic complexes, such as sulfate and nitrate, present in the ash may enter the ground water and contaminate present or future drinking water sources. Evidence is still inconclusive as to the degree of hazard of the ash materials (GAI Consultants, Inc. 1979).

The water soluble content of fly ash ranges from very little to several percent. The principal ions contained in ash leachate are calcium and sulfate, with smaller quantities of magnesium, sodium, potassium, and silicate ions present (Table 2). Free lime (CaO) accounts for part of the soluble calcium. The soluble sulfate is approximately half the total sulfate (SO_4) present in the fly ash. Fly ash leachate may be alkaline or acidic, depending on the type of coal burned.

TABLE 1

LITERATURE REVIEW OF ASH SOLIDS ANALYSES (in ppm)

Substance	Fly Ash Range			Avg.	Data Pts.
Arsenic	6	-	1,200	177	23
Barium	100	-	1,074	520.7	6
Cadmium	0.29	-	51	10	17
Chloride		-		1,000	1
Chromium	15	-	900	218.6	18
Copper	16	-	400	171	17
Fluoride	120	-	671	396	2
Iron	49,000	-	235,000	124,125	8
Lead	11	-	800	210.7	19
Manganese	100	-	1,000	389	16
Nitrate		-		85.6	1
Selenium	6.9	-	760	145	14
Silver		-		3	1
Sulfate		-		5,430	1
Zinc	50	-	9,000	1,314.3	20

Substance	Bottom Ash Range			Avg.	Data Pts.
Arsenic	0.5	-	18	7	14
Barium	300	-	731	481.6	7
Cadmium	0.5	-	3	1.25	12
Chloride		-		-	-
Chromium	15	-	895	213	13
Copper	12	-	300	87.2	12
Fluoride		-		10.6	1
Iron	66,000	-	211,900	116,100	9
Lead	3	-	30	13.2	11
Manganese	100	-	1,000	438.7	15
Nitrate		-		16	1
Selenium	0.08	-	20	5.45	11
Silver		-		-	-
Sulfate		-		675	1
Zinc	20	-	400	142	12

Source: D. W. Weeter and M. P. Bahor. Technical Aspects of the Resource Conservation and Recovery Act Upon Coal Combustion and Conversion Systems. Oak Ridge National Laboratory, February 1979. ORNL/OGPA-10.

TABLE 2

LITERATURE REVIEW OF ANALYSES OF ASH POND DISCHARGES (in ppm)

Fly Ash Pond

Substance	Range		Avg.	Data Pts.
Arsenic	0.01	– 1.1	0.38	3
Barium	0.2	– 0.3	0.25	2
Cadmium	0.001	– 0.037	0.019	2
Chloride	6	– 7	6.5	2
Chromium	0.02	– 0.067	0.044	2
Copper	0.02	– 2.4	0.91	3
Cyanide		–	–	–
Iron	1.44	– 630	211.12	3
Lead	0.01	– 0.91	0.33	3
Manganese	0.13	– 0.48	0.31	2
Selenium	0.002	– 0.33	0.12	3
Silver		–	–	–
Sulfate	209	– 358	283.5	2
Zinc	0.06	– 2.2	1.26	3

Bottom Ash Pond

Substance	Range		Avg.	Data Pts.
Arsenic	0.006	– 0.018	0.012	2
Barium	0.1	– 0.2	0.15	2
Cadmium	0.001	– 0.003	0.002	2
Chloride	7	– 8	7.5	2
Chromium	0.009	– 0.01	0.095	2
Copper	0.041	– 0.065	0.053	2
Cyanide		–	–	–
Iron	5.29	– 5.98	5.64	2
Lead	0.02	– 0.02	0.02	2
Manganese	0.16	– 0.58	0.37	2
Selenium	– 0.002	– 0.011	0.007	2
Silver		–	–	–
Sulfate	49	– 139	94	2
Zinc	0.09	– 0.14	0.12	2

Combined Ash Pond

Substance	Range		Avg.	Data Pts.
Arsenic	0.005	– 0.038	0.038	9
Barium	0.1	– 0.2	0.19	10
Cadmium	0.001	– 0.005	0.002	6
Chloride	3	– 14	7.2	10
Chromium	0.004	– 0.043	0.015	10
Copper	0.01	– 0.08	0.042	10
Cyanide	0.01	– 0.05	0.03	3
Iron	0.23	– 2.3	0.8	10
Lead	0.01	– 0.025	0.014	10
Manganese	0.01	– 0.39	0.09	9
Selenium	0.003	– 0.065	0.016	10
Silver		–	0.01	1
Sulfate	59	– 156	109.7	10
Zinc	0.03	– 0.12	0.053	10

Source: Same as Table 1.

The ash samples for this study were analyzed by two methods, 1) acid digestion for total element content, and 2) leached according to the U.S. EPA EP Toxicity (45FR33127; May 19, 1980) determination procedures.

B. Metal Toxicity

1. Aluminum

Aluminum (Al) is one of the most abundant elements on earth and is a constituent of all soils, plants, and animal tissues. It does not occur naturally as the pure insoluble metal, although many of its salts are readily soluble. However, aluminum does not exist long in surface waters, as it precipitates or is absorbed as aluminum hydroxide, etc. (McKee and Wolf, 1963).

The toxicity of aluminum compounds to aquatic organisms varies for a given compound and organism (McKee and Wolf, 1963). At present, EPA has not established water quality criteria for the protection of aquatic organisms from aluminum compounds.

2. Arsenic

The principal emission source of arsenic (As) in the United States is reported to be coal-fueled power plants which produce approximately 3,000 tons of As per year (Sittig, 1980).

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In natural waters As occurs predominately as soluble in-organic arsenate (+5). Elemental As exhibits relatively low toxicity because of its low solubility (Sittig, 1980).

Arsenic is known to bioconcentrate in both fresh and salt-water organisms and is toxic to invertebrates and verte-brates. In comparable studies, As toxicity (LC_{50} values) was lower in freshwater than marine organisms, with fish exhibiting less tolerance than invertebrates (Sittig, 1980). The EPA criterion for protection of freshwater aquatic life is 57 ug/1 as a 24-hour average, and concentrations should never exceed 130 ug/1 at any time. For saltwater organisms, the protection values are 29 ug/1 and 67 ug/1, respectively.

3. Chromium

Chromium (Cr) is a commonly occurring element in the earth's crust (approximately 125 mg/kg); however, substantial con-centrations are rarely found in natural waters. Industrial processes are a substantial source of Cr in natural waters, with coal combustion contributing an important fraction (Sittig, 1980).

In the aquatic environment, Cr occurs predominately as Cr^{+3} or Cr^{+6}. The oxidation and reduction of valence states of Cr are complex processes which are pH and temperature de-pendent. However, in general, hexavalent Cr is a strong oxidizing agent which is readily reduced to trivalent Cr which is biologically reactive with a variety of organic molecules (e.g., DNA and RNA). The uptake of Cr^{+6} by liv-ing organisms generally exceeds that of Cr^{+3} for solubility reasons (Sittig, 1980).

The toxicity of Cr is widely recognized, but toxic effects are complicated due to the existence of many Cr compounds which may contain Cr of different valences with distinct chemical, physical, and toxicological properties (Sittig, 1980). For protection of freshwater aquatic life, the EPA criterion for hexavalent Cr is 10 ug/l as a 24-hour average and should not exceed 110 ug/l at any time. For saltwater organisms the values are 25 ug/l and 230 ug/l, respectively. The value for trivalent Cr in freshwater is variable, being dependent on hardness, and no level has been established for saltwater (Sittig, 1980).

4.   Selenium

The primary source of selenium (Se) in the environment is the weathering of rocks and soils; however, world-wide approximately 3,500 metric tons per year originate from human sources. Se may be an oxidizing or reducing agent, depending on its valence state which may range from -2 to +6. Se^{-2} reacts with metals to form heavy metal selenides which are extremely insoluble. The solubility of other selenium compounds may range from highly soluble to very low solubility (Sittig, 1980).

Selenium is acutely toxic to aquatic invertebrates and fishes, although toxicity is dependent on synergistic and antagonistic elements. The EPA criterion for protection of freshwater aquatic life is 9.7 ug/l as a 24-hour average, and concentrations should never exceed 22 ug/l at any time. For protection of saltwater organisms, the criterion is 4.4 ug/l over 24 hours and not to exceed 10 ug/l at any time (Sittig, 1980).

C. Trace Metal Behavior in Aquatic Systems

1. Abiotic

The behavior of trace metals which reach aquatic systems in the dissolved state is governed by the rules of coordination chemistry which deals with complex formation (Stumm and Morgan, 1970). The activity of trace metals is primarily influenced by the stability of the element-complex but is also affected by oxidation-reduction (redox) potential and pH (Brooks, 1977).

Permanent or predictable equilibrium between the available and chemically/physically bound fractions of trace elements have not been recognized. This is due to the following dynamic physical, chemical, and biological processes which continually modify the chemical activity and concentration of trace metals: temperature, salinity, solubility, water hardness, and additional biological and chemical factors.

The major portion of metal transport in rivers is through organometallic particulates, with only a small amount carried in solution. These complexes compose the class of organic acids, including humic acids, which make up the major portion of organic matter in soils and water. Humic acids have strong chelating properties for trace elements. However, in water of high inorganic mineral content, the carbonate and bicarbonate fractions become major binding agents (Dvorak et al., 1978).

In sediments, metals are associated with organic compounds and/or clays. Metals (e.g., Hg, Cd, As) are often transported in the suspended particulate fraction and later in-

corporated in the sediments in areas of deposition. In
general, mobilization of trace metals in aquatic systems is
greatly dependent on redox potential and pH. Alkaline sys-
tems produce precipitation of insoluble hydroxides and sul-
fides, while systems which are strongly acid promote solution
of many metals which increase their bioavailability (Dvorak
et al., 1978).

2. Biotic

The three major types of differential uptake of trace ele-
ments by biota are defined as follows: 1) bioaccumulation,
which is the ability of an organism to concentrate an ele-
ment above abiotic levels; 2) bioconcentration, which is the
influence of size and/or age on elemental concentrations
within an organism; and 3) biomagnification, which is the
successive increase of trace element concentration with
trophic level transfer (Dvorak et al., 1978).

Microorganisms are an important factor affecting the chemical
form and concentration of trace elements in that they can
convert inorganic complexes to organometallic compounds,
resulting in increased bioavailability. Examples relevant
to this study are the conversions of selenium to dimethyl
selenide and arsenic to an organometalloid. Bacteria also
bioaccumulate metals in solution with subsequent transfer of
contaminants up the food chain (Patrick and Loutit, 1976).

Phytoplankton, aquatic bryophytes, and rooted aquatic macro-
phytes are all known to accumulate metals (Dvorak et al.,
1978).

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The capacity of algae to accumulate trace elements has resulted in their use as indicator organisms. The ability of aquatic plants to accumulate and maintain trace elements can be useful in determining the possibility of periodic discharges of trace metals (e.g., from storm events, etc.) when high concentrations may not be present at all times. This characteristic may prove to be important at the Vienna site.

Concentration factors for various trace elements in algae, aquatic bryophytes, and aquatic macrophytes vary with the specific plant and element (Dvorak et al., 1978). Mayes and McIntosh (1975) suggested that plants other than algae be utilized as indicators of trace metal contamination due to the high concentration factors displayed by algal species. The effects of trace metals on aquatic plants include: changes in physiology, productivity, community composition, and species abundance (Dvorak et al., 1978).

Toxicity of trace elements in invertebrates is element and species specific. Acute toxicity may not be as important to invertebrates as the sublethal effects which exhibit two types of effects: 1) reduce the fitness of the organism and 2) alter community structure and function, which is a result of the first effect. These effects manifest themselves as a reduction in the biomass, nutrients, and/or energy for transfer to higher trophic levels (Dvorak et al., 1978).

Fish take up trace elements through two primary pathways: 1) absorption through the gills and 2) ingestion (via feeding). The latter is considered to be the major source of contamination; however, trace metal concentrations are often lower

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in the predator than prey. Uptake is influenced by the chemical form and water quality. In general, the toxicity of metals decreases as hardness, CO_2, and pH increase.

Direct lethal effects of trace metal contamination in fishes have been linked to failure of specific organs, e.g., the gills and liver. Sublethal effects include interference with neuro- and physiological processes which reduce fitness. A significant result of reduced fitness is increased susceptibility to predation (Dvorak et al., 1978).

In summary, trace metals usually are primarily found in the sediment, as relatively small amounts exist in the dissolved state. Trace elements are bioaccumulated by rooted macrophytes and benthic invertebrates from the substrate. Phytoplankton adsorb trace elements to their cell walls and absorb them internally. The greatest bioaccumulation is exhibited generally by the lower order consumers (e.g., grazers and detrital feeders). Fishes obtain trace metals primarily from food organisms; however, trace metal concentrations are often lower in the predator than prey, which is counter to the biomagnification theory (Dvorak et al., 1978).

SECTION III

DESCRIPTION OF STUDY AREA

A. Surface Drainage

The Vienna ash disposal site was located and described in
Section I. The present surface drainage of the Vienna marsh
system near the fly ash disposal site is influenced primar-
ily by tidal and Nanticoke River currents. A single tidal
stream (Bridge Creek) system drains the site and the land-
ward shrub and forest lowlands directly east of the site
(Figure 2). Aerial photographs taken for DP & L show that
when the channel surrounding the disposal site was created,
the northernmost headwaters of Bridge Creek were opened to
the Nanticoke River (Figure 3). Three branches of the creek
were impounded within the disposal site. Overflow from the
disposal site, as initially constructed, was from the north-
eastern corner into the surrounding moat channel. Some time
after fly ash disposal ceased, the dike surrounding the site
was breached at a number of places along the eastern border
(Figure 3) (personal communication, Mr. John Dick, DP & L,
Vienna, MD).

Net flow from the site and most of Bridge Creek under ex-
isting conditions apparently is southward into the Nanticoke
River. However, the northern portion of this "marsh water-
shed" now is tidal to the north into the Nanticoke River,
especially on the ebb tide. High seasonal flood
flows of the Nanticoke River can enter the disposal site in
its northeastern corner and also flow through the main stem
of Bridge Creek via the disposal site eastern channel (moat).
Ebb tide and high water flows of the river also flow into

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Scale: 1" = 500'

Legend

Marsh

Lowland Shrub and
Mixed Forest

Vienna

NANTICOKE

RIVER

Vienna
Power Plant

DORCHESTER COUNTY
WICOMICO COUNTY

WICOMICO COUNTY
DORCHESTER COUNTY

Ferry Point
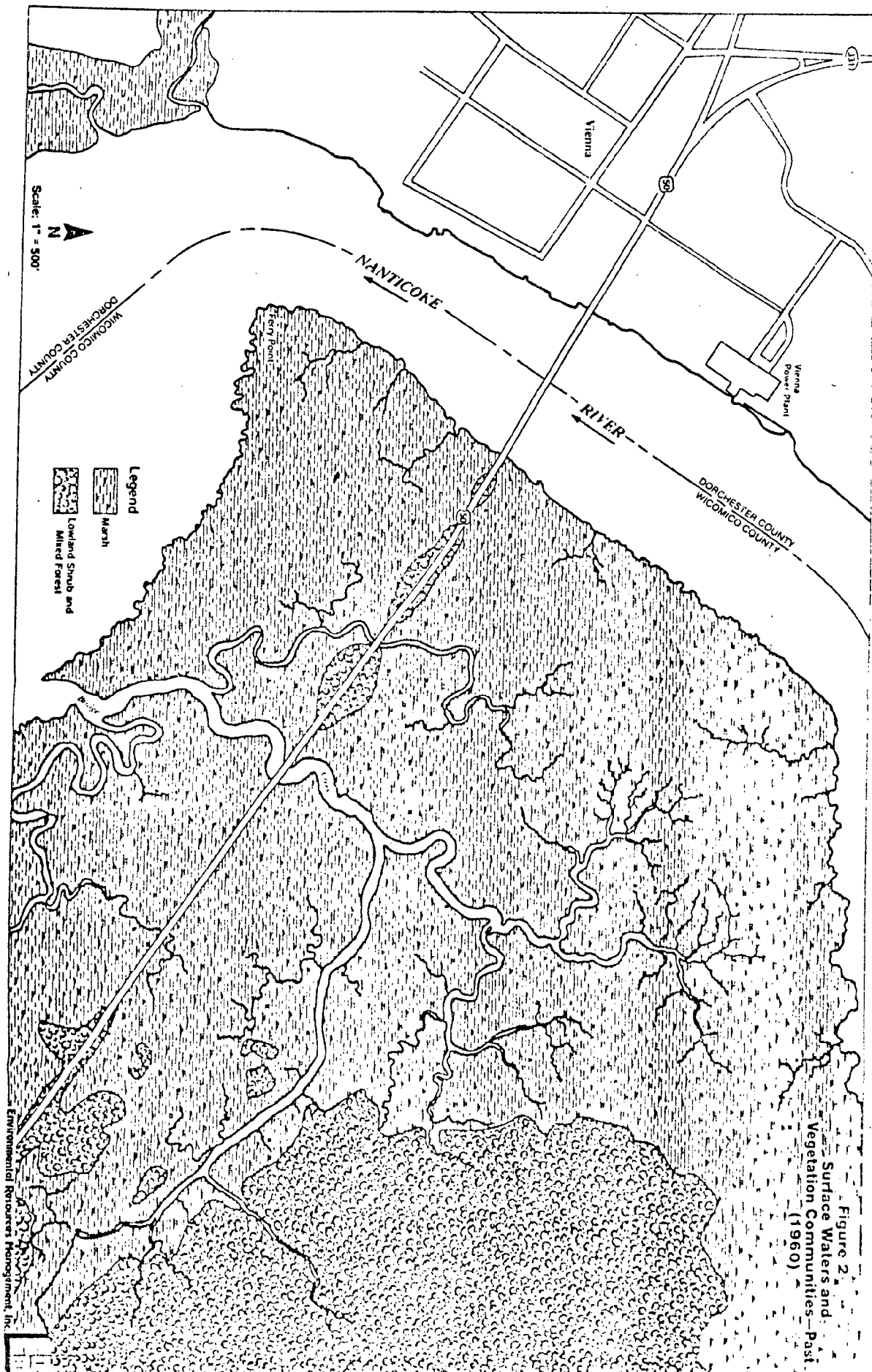
Figure 2.
Surface Waters and
Vegetation Communities—Past
(1960)

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Vienna

NANTICOKE

RIVER

Vienna
Power Plant

DORCHESTER COUNTY
WICOMICO COUNTY

Unvegetated
Discharge Point

WICOMICO COUNTY
DORCHESTER COUNTY

Scale: 1" = 500'

N

Ferry Point

Legend

Marsh

Lowland Shrub and
Mixed Forest

Wetland to Lowland Shrub

Phragmites

★ Dike Breach Points

Mosquito Ditches

FLY ASH DISPOSAL AREA

Moat Open to River

Overflow Pipes

Moat

Figure 3
Surface Waters and
Vegetation Communities—Present
(1978)

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the site channel on its western border from openings to the north. The creek channels in the disposal site are reduced to small trickles at low tide, and the site moat is not navigable with a flat bottom boat during this low water period. Local hydrological conditions are also altered somewhat by mosquito ditches put in by the Maryland Agriculture Department in the 1960's (Lesser, 1982).

B. Regional Geology

The geologic and hydrogeologic characteristics of the area determine the vulnerability of ground and surface waters to contamination. Therefore, a literature review was conducted to determine the three-dimensional hydrogeologic characteristics of the area. This report addresses only those sub-surface geologic units which may be used for ground water supply in the vicinity of the site.

The disposal site under study is located in the sediments of the Atlantic Coastal Plain, a thick sequence of unconsolidated marine and fluvial deposits forming the western edge of the Atlantic continental shelf (Rasmussen et al., 1957). These sediments consist of units of sand, gravel, clay, and silt in varying proportions and thicknesses, which form a wedge thickening to the southeast. This wedge thins toward the northwest, terminating at the contact with the metamorphic rock complex of the Piedmont Physiographic Province.

The Coastal Plain sediments range in age from Lower Cretaceous through Holocene. The total thickness of the sedimentary sequence in this area is estimated to be 3,000 to 4,000 feet (Rasmussen et al., 1957).

The deepest significant geologic unit in the Vienna area is
the Piney Point Fm., which occurs at about -600 feet in ele-
vation (Mack et al., 1971). Although it is not presently
used in the area, moderate transmissivity and good water
quality offer a potential for ground water development. The
Piney Point is confined above by the Calvert Fm. This for-
mation contains a sand unit called the Federalsburg Aquifer,
but poor water quality precludes its use as a major water
source. Overlying the Calvert is the Choptank Fm. which
contains the Frederica Aquifer, a minor aquifer which is
used little in the Vienna area.

Overlying the Choptank, and generally considered to be the
uppermost major Coastal Plain unit in the Vienna area, is
the St. Mary's Fm. (Mack et al., 1971). This formation
consists of silty clay and clayey silt. Although some fine
shells and sand are present, the formation functions as an
aquiclude above the Choptank Fm. As such, it is not used
for water supply. Its upper surface occurs from elevation -
90 feet to elevation -100 feet in the area. This formation
forms the top of the pre-Pleistocene southeastward dipping
coastal plain deposits in the Vienna area. Its upper boundary
is considered to be an erosional surface, although area
borings indicate that the actual erosional surface may be in
a thin veneer of overlying Manokin Fm. silts (Delmarva Permit
Application, 1979). One report cites a vertical permeability
of less than 1 x 10^{-8} cm/sec for the St. Mary's (Geraghty
and Miller, 1980). Thus, leakage to the underlying Choptank
aquifer is very slow.

The Salisbury Fm. is the uppermost aquifer unit in the area.
It consists of Pleistocene age sediments which were de-
posited on the Miocene erosional surface (Mack et al., 1971).
It contains two major facies. The upper unit, or Beaverdam
facies, consists of lenticular light colored quartz sand and
silt. The lower unit, or Red Gravelly facies, consists of
red to brown sand and gravel. An upper discontinuous unit
called the Walston Silt is present in some parts of the
Vienna area, near the top of the Beaverdam. This fine
grained unit has been defined beneath the power plant prop-
erty west of the Nanticoke River. The Salisbury Fm. is used
as an aquifer in the Vienna area. In some areas it is under
water table conditions, and in others is confined by the
Walston Silt. Limited aquifer test data indicate the trans-
missivity of the unit to range up to 100,000 gpd/ft in some
areas. In the Vienna area, aquifer tests indicated a range
from 7,800, near Vienna, to 66,000 gpd/ft toward the west
(Delmarva Power and Light Company, 1978). The water quality
in the Salisbury Fm. is generally good, with TDS ranging
from about 600 ppm near the Nanticoke River, to as low as
less than 100 ppm away from the river.

River and Tidal Marsh deposits constitute units of signifi-
cance to this study. These sediments consist of alluvial
point bar deposits which were laid down on the insides of
meanders in the Nanticoke River, and the organic root mat of
tidal marshes that overlie the channel deposits. The river
deposits consist of dark brown silt with a trace of sand and
infrequent lenses of clayey silt. Where the organic marsh
mat has formed, the silt contains dense decaying organic
matter, both root and upper plant remains.

The present surface drainage system on the coastal plain, including the Nanticoke River, is thought to have formed quickly and developed mature drainage characteristics, such as broad meanders, when sea level was considerably lower than at present. When the sea level rose, the base level of erosion rose, and the meandering rivers began to backfill their inundated estuarine channels rapidly, developing the tidal marsh system present today (Rasmussen et al., 1957). The present point bar sediments consist mainly of silts and clays (Mack et al., 1971), deposited in the low energy estuarine environment.

C. Site Geology

The study site lies on the inside of a meander in the Nanticoke River. The river channel is cut into sediments of the Salisbury Fm. East of the fly ash disposal site, in the Salisbury, Maryland, area and west of the site at the Vienna power plant, previous studies have defined a large paleochannel cut into the Miocene sediment surface, probably during the Illinoisan glaciation (Hansen, 1966). This paleochannel represented a major drainageway to the sea on the east. Although no borings are available under the fly ash disposal site itself, subsurface mapping both east and west of Vienna indicates that the center line of the paleochannel passes directly beneath the site (Hansen, 1966; and Mack et al., 1972). Thus, the deposits of the Pleistocene Salisbury Fm. beneath the site are paleochannel fill deposits. These deposits presently constitute the local shallow aquifer in the Vienna area, with the ground water discharge mainly to

the Nanticoke River. Projecting available data from the power plant area indicates that the bottom of the Pleistocene deposits occurs from about elevation -100 to -80 feet beneath the study site (Geraghty and Miller, 1980).

The disposal site occupies a tidal marsh which has developed inside a Nanticoke River meander. Thus, the sediments directly beneath the site are the Nanticoke River point bar silts and organic marsh deposits.

D. Flora

The marshes of the Nanticoke River at Vienna have been subjected to numerous disturbances (highway and transmission corridors, ditching, filling, etc.) and exist in brackish waters near the transition zone of salt to fresh water. Field survey and photo interpretation techniques were used to create the generalized vegetation community maps as per 1960 conditions (Figure 2) and 1978 to present conditions (Figure 3). The only photographic records found and available to date are from October 1960 (USGS, Reston, VA) and October 1978 (Air Survey Corp., Reston, VA) overflights. The older photo is black and white, while the latter record is in both black and white and false color infrared. Large prints of both, at a scale of 1" = 400', were acquired for purposes of this study (from Air Survey Corp.).

Dominant plant species (identified by several reconnaissance surveys) of these diverse marshes include giant cordgrass (Spartina cynosuroids), switch grass (Panicum virgatum),

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marsh hibiscus (Hibiscus spp.), and some Olney three-square
(Scirpus olneyi). These marshes can be classified as a Type
16 salt meadow wetland, but species now in and around and
landward of the disposal site are more indicative of a Type
12 shallow fresh marsh (Shaw, 1956). Although not observed,
there may be Spartina alterniflora (saltmarsh cordgrass)
also present. Species such as arrow-arum (Peltandra virgin-
ica) and rice cut-grass (Leersia oryzoides) are also present,
as is Baccharis halimifolia (groundsel-bush) especially on
the slightly drier berms created around the disposal site.
Toward the heads of the tidal creeks (inside as well as
outside of the disposal area), the brackish water species
are further displaced by freshwater macrophytes, such as
cattails (Typha spp.), rush species, and large stands of
arrow-arum.

The present ERM study (see Section V, Biological Investiga-
tions) has shown that the wetland soils inside the disposal
area and on the surrounding berms have become revegetated.
The berm was created by dredging up the marsh and underlying
soils to enclose the disposal area. The fly ash that was
slurried into the site between 1966 and 1972 buried about 80
percent of the enclosed marsh. Aerial photographs revealed
that by 1978 all but a small area (about 400 sq. ft.) at the
very end of the pipe was revegetated. Numerous test holes
were dug throughout the site and revealed that the ash de-
posit forms a layer from 1 to 3 feet thick over the original
marsh mat of organic matter. The ash layer is now support-
ing a monotypic community of Phragmites. Phragmites also
covers portions of the berms, where in large part a shrub
swamp or lowland open field community tends to be establish-
ing itself. The species composition of these successional

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communities on the disturbed substrates is very heteroge-
neous, dependent on plant dispersal mechanisms and also
moisture content of sites. Any of the above mentioned species
(especially those favoring drier sites) may be present, but
mixtures of the following were also observed: winged sumac
(Rhus copallina), tickseed-sunflowers (Bidens spp.), Aster
spp. and possibly marsh Boltonia, as well as grasses, rushes,
sedges, and ferns. Some of these formed dense communities
inside the dike and reflected aspect dominance at least
during the fall of the year.

The U.S. Route 50 roadway and embankment which crosses the
marsh and the extensive mosquito ditching, throughout, un-
doubtedly caused many changes in the hydrologic functioning
of the marsh to the north and south of the road. However,
no baseline information is available that documents these
changes. There has also been construction and expansion of
the power line right-of-way north of and parallel to Route
50, which has involved some filling and clearing activity in
the marshes and adjacent woodland. The species composition
of the marsh and the filled areas has been undergoing a
successional change for many years in response to these
major perturbations. An artificial shrub swamp has been
developing along these disturbance fill areas. Members of
this community are representative of the shrub swamp forming
the eastern border of the Vienna marsh which has been clas-
sified as a Type 6 shrub swamp wetland (Shaw, 1956). Also,
see Appendix A.

E. Fauna

1. Aquatic

Typical of brackish water, the invertebrate diversity at the
Vienna marsh is relatively low; however, most of the species
found occur in abundance. Amphipods dominate the microin-
vertebrate population and are an important food for juvenile
fishes. Other invertebrates include mud crabs, balanoid
barnacles, gilled snails, ectoprocts, copepods, sea nettles,
lion's mane jellyfishes, and small numbers of blue crabs
(Delmarva Power, 1979).

Fishes commonly found in the Nanticoke River are listed in
Table 3. The Nanticoke River above and below the Route 50
bridge is an important spawning ground for anadromous fish,
many of which are important commercial and game species.
The Nanticoke River is one of four principal spawning areas
for striped bass in the Chesapeake Bay area. Striped bass
spawn from Round Island Point upstream to Sharptown, but
spawning is typically heaviest at Vienna where environmental
conditions such as temperature, salinity ranges, moderate
turbulence, and low turbidity are optimal (Delmarva Power,
1979).

2. Terrestrial

Vertebrates are common to the wetland marsh and shrub areas.
Fifty-five species of amphibians and reptiles are reported
for the Eastern Shore region. Based upon habitat require-
ments, approximately 20 species are believed to inhabit the
Vienna marsh (Delmarva Power, 1979). A species list is pro-
vided in Appendix B.

TABLE 3

FISHES OF THE NANTICOKE RIVER
IN THE VICINITY OF VIENNA, MARYLAND

Species	Commercial/Sport Importance	Anadromous
American Eel	X	
Ladyfish		
Blueback Herring	X	X
Alewife	X	X
American Shad	X	X
Atlantic Menhaden	X	
Gizzard Shad	X	
Bay Anchovy		
Chain Pickerel		
Carp		
Golden Shiner		
Satinfin Shiner		
White Catfish	X	
Brown Bullhead	X	
Atlantic Needlefish		
Banded Killifish		
Mummichog		
Striped Killifish		
Rough Silverside		
Tidewater Silverside		
Atlantic Silverside		
White Perch	X	X
Striped Bass	X	X
Pumpkinseed	X	
Largemouth Bass	X	
Tessellated Darter		
Yellow Perch	X	
Bluefish	X	
Silver Perch	X	
Spotted Seatrout	X	
Spot	X	
Atlantic Croaker	X	
Naked Goby		
Hogchoker		

Sources: Academy of Natural Sciences of Philadelphia. 1971.
Nanticoke River Surveys 1969 and 1970.

Maryland Department of Natural Resources, Fisheries
Administration. Seining Records 1972-74.

Approximately 15 bird species occur in the vicinity of Vienna
(Delmarva Power, 1979). Common year-round species include
eagles, vultures, hawks, osprey, pheasants, owls, woodpeckers,
and songbirds. Among these, pheasants and some songbirds
will physically inhabit the marshes, while the others include
the marshes as part of their feeding territory. Waterfowl
are seasonally abundant in the Chesapeake Bay and Vienna
marshes since the Bay area is the principal gathering place
on the Atlantic coast during migration. Geese, ducks, and
swans begin moving into the Bay region from the north in
October, reach population peaks in December and January, and
return northward in March (Stewart and Robbins, 1958).

Some species such as mallards, black ducks, wood ducks, and
teals are typically associated with the brackish-freshwater
environment found around Vienna. The fly ash site is an
important roosting area for wood ducks during the fall mi-
gration. Numerous shore birds and waders also dwell in the
Vienna marsh, including herons, rails, white ibis, gulls,
and occasional terns. Marsh usage by these birds is vari-
able; some may be resident breeders, transients, or stragglers
(BNW Refuge, 1976).

There are some 15 species of mammals in the project area
marshes and uplands (Appendix C). Many mammals which are
found in wetlands will also inhabit the uplands, such as
striped skunk, raccoon, and red fox. The most dominant
mammal found in the Vienna marsh ecosystem is the muskrat;
white-tailed deer are also abundant. The stream banks and
tidally exposed banks of the channel moat around the dis-
posal site are riddled with muskrat burrows and trails.
Only one muskrat house was sighted during sampling surveys,
and that was in the Nanticoke control site area. Numerous

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signs of raccoon were also seen along the dike of the dis-
posal site. Numerous signs observed at one location along
the eastern dike indicated extensive raccoon usage. At this
breach location they were apparently feeding on crayfish.

3.   Threatened and Endangered Species

The Delmarva Fox Squirrel is believed to inhabit portions of
the greater Vienna area but not the marshes. Its prime hab-
itat is mature woodland, loblolly pine, and hardwood forests
along the western bank of the Nanticoke between Marshyhope
Creek and Penknife Point.

One pair of southern bald eagles is known to nest in the
vicinity of Point No Point south of Vienna (Delmarva Power,
1979). These birds prefer tall trees adjacent to marshy
areas. The southern bald eagle is generally declining
throughout its range due to human encroachment on primary
nesting areas and reduced reproduction from bioaccumulation
of toxic substances.

Osprey also nest along the Nanticoke River near Vienna. Al-
though it is not officially classified as rare or endangered,
the osprey is declining in most regions and may be seriously
threatened. The Chesapeake Bay has the largest breeding pop-
ulation known in North America.

The swamp sparrow has been reported nesting close to the
ground in stands of giant cordgrass in the Vienna marsh.
This species is not threatened, but it is unique in south-
ern locations.

SECTON IV

HYDROGEOLOGIC INVESTIGATION

A. Site Reconnaissance

An initial site reconnaissance was conducted for the purpose
of assessing site conditions and access. This reconnaissance
revealed that site conditions were such that detailed hydro-
geologic investigation could not be conducted as planned.
The conditions encountered and the consequent problems in
performing the work were as follows.

a) Access to the site is possible only by boat,
    and is further restricted during low tide by
    shallow water and by shallow pilings in the
    south and east sections of the moat surround-
    ing the fly ash disposal area. This precluded
    the use of heavy equipment such as backhoes
    or drilling rigs on the site, as had been
    originally envisioned. These conditions also
    restricted working hours to high and mid tides,
    and tended to restrict water sampling to pe-
    riods when tidal waters were mixed with site
    ground water and surface water.

b) The area containing the major portion of the
    fly ash deposit is covered by a thick stand of
    Phragmites reed grass. The grass obstructed
    vision and access, making a topographic survey
    of the site unfeasible.

c)   The site is a shallow marsh with a hummocky
     vegetated surface in very soft silt.   This
     terrain, plus the Phragmites stand, made ac-
     cess to the interior time consuming.

Since installation of piezometers was critical to the hydro-
geologic study, the feasibility of using an all-terrain-
vehicle mounted drilling rig was explored.   Several drillers
were contacted, but none was found who could supply a dril-
ling rig which could perform the necessary work at the site.
It was decided, therefore, that any well points or pie-
zometers would be installed using a hand auger.

B.   Methods

1.   Fly Ash Distribution

Reconnaissance work was conducted to determine the distri-
bution and nature of the site topography and drainage, and
to determine the areal and vertical distribution of the fly
ash deposits on the site.   This was determined by walking
the site, checking for fly ash presence and depth with a
hand auger and a shovel.

2.   Well Point Installation

Well Point V-1 (Figure 4) was installed by hand auger, using
a 3 1/2 inch diameter bucket soil auger.   An 18-foot deep
boring was made, which showed the fly ash to be about 3 feet
thick and to be underlain by a 9-foot thick swamp mat of

Figure 4
Well Construction at Location V-1

- PLASTIC CAP
- BENTONITE SEAL
- 2" I.D. SCHEDULE 40 PVC WELL CASING
- SAND PACKING
- 2" I.D. SCHEDULE 40 PVC .010 WELL SCREEN
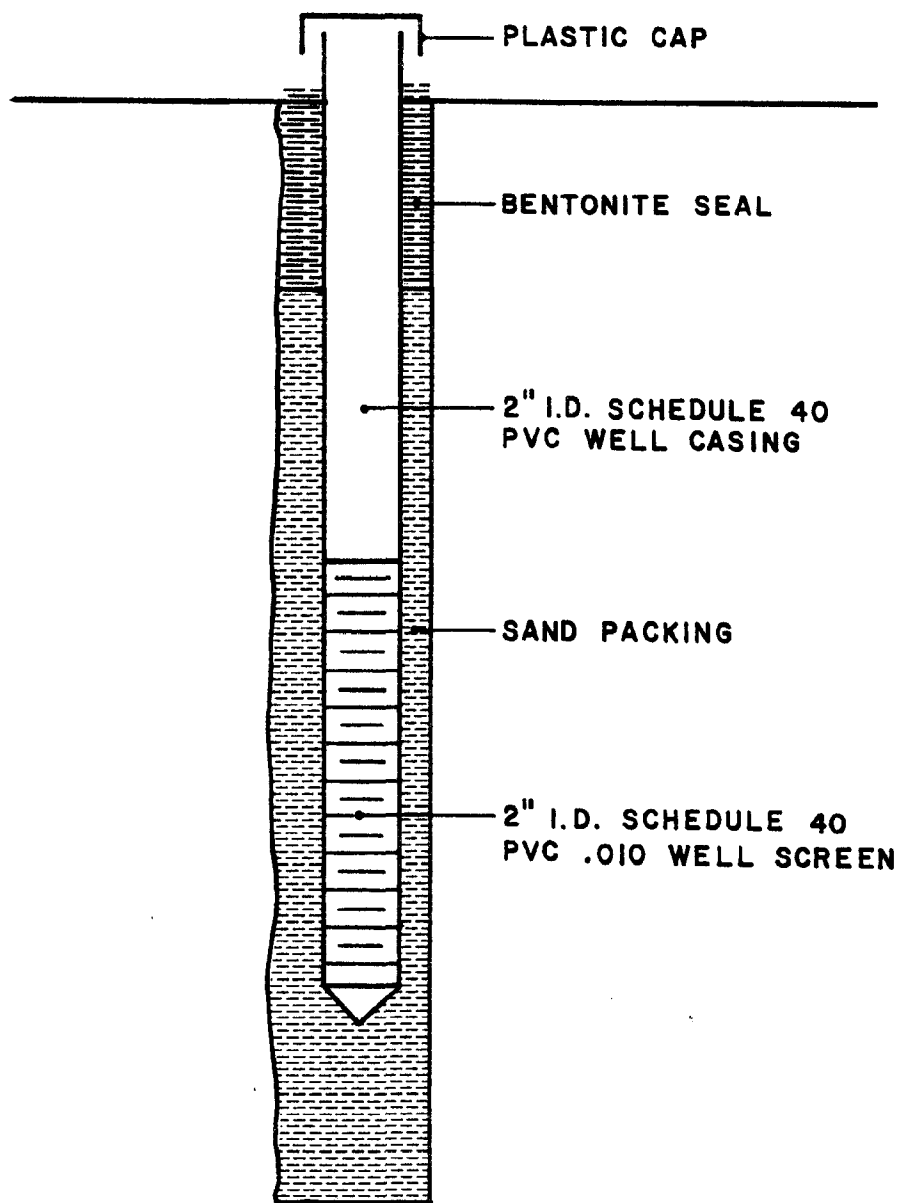
silt and decaying organic material. Underlying the swamp
mat were alternating layers of runny, flowing dark gray
silt, clayey silt, and plastic silty clay. At 18 feet a
white medium grained quartz sand unit was encountered. The
boring was terminated because of the length and weight of
the auger string. The log of this well is included in
Appendix D.

The runny silt quickly backfilled the boring to the 12-foot
level. A 5-foot long, 1 1/2 inch diameter Schedule 40 PVC
.010 well screen was installed in the hole. One and one-
half inch Schedule 40 PVC casing extended above the surface
(Figure 4). Sand packing was poured into the hole as a base
for the well point, and the outer annulus was sand packed
around the screen. Two feet of bentonite seal were installed
at the surface. The final depth of the well was 9 feet.

Five additional attempts to install well points elsewhere at
the site were unsuccessful. The clay fraction of the sedi-
ments which held the hole open at V-1 were not encountered
elsewhere on the site, and the running silts filled the bor-
ings almost to the surface. Establishing additional well
points would require use of drive casing and wash equipment,
and possibly mud to stabilize the Pleistocene sands for well
screen installation. Since site conditions precluded the
use of such methods, the hydrogeologic investigation was
limited to the investigation of the shallow ground water
quality and surface water quality. The one well was insuf-
ficient to provide further data on deeper ground water qual-
ity or on ground water flow system dynamics at the site.

3. Sampling

Ground water, surface water, and fly ash samples were col-
lected from representative areas of the site. On November
19, one set of five ground water samples were collected at
locations V-1, V-2, V-3, V-4, and V-7 (Figure 5). The sam-
ples were obtained from the top of the saturated zone in the
limited areas where ground and surface waters are not contig-
uous as a marsh. The samples were obtained by hand augering
into the root mat layer with a 3 1/2 diameter inch bucket
auger and terminating the hole before encountering running
silt. The ground water was evacuated with a hand pump and
allowed to recover. A sample was obtained from the hole by
bailing, and specific conductivity was measured. Two 500 ml
plastic bottles were filled with ground water at each sam-
pling location. The bottles were filled completely to min-
imize entrained air, packed in ice, and delivered to Lancaster
Laboratories for chemical analysis. The auger borings were
then deepened to locate the running silt unit.

On November 19, one set of nine surface water samples were
collected on and near the site at locations V-5, V-6, V-9,
V-11, V-12, V-13, V-14, and V-15. These locations are shown
on Figure 5. One additional sample was collected at V-19 on
December 10. Samples obtained at locations V-5 and V-9
represent surface water quality conditions within the fly
ash deposits, since they directly drain the fly ash deposits.
Samples V-6 and V-11 were collected to determine surface
water quality leaving the site. Samples V-12 and V-15 were
collected from the moat, and V-14 from Bridge Creek to de-
termine surface water quality in the major drainageways
adjacent to the site. Samples V-13 and V-19 were collected
to determine natural surface water quality in the tidal
marsh environment near the fly ash site, and remote from it

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Figure 5
On-Site and Adjacent Water Quality Sampling Locations

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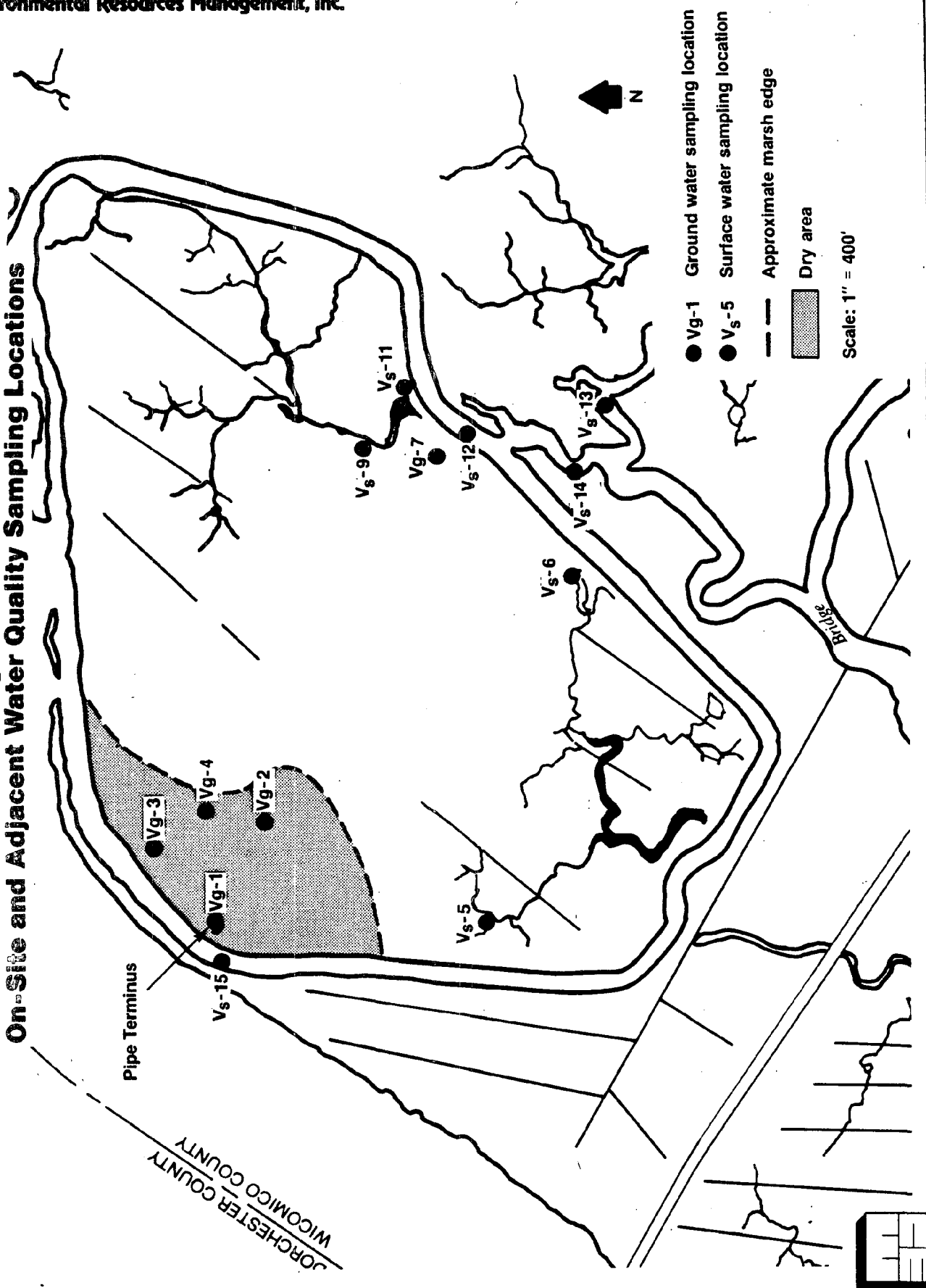
(Figure 6). As with the ground water samples, two 500 ml plastic bottles were filled at each sampling location and packed in ice. Samples were collected during ebb tide to ensure that the water collected had been in contact with the fly ash site.

On October 6, samples Ph-6 and Ph-7 were collected near the pipe terminus at location VS-1. On November 4, 12, and 19, one set of ten fly ash samples was collected at locations VS-1, VS-3, VS-4, VS-16, and VS-17 in the dry area and at VS-8 and VS-10 in the marsh area. These locations are shown in Figure 7. At location VS-1, sample VS-1A was taken from the surface, sample VS-1B from a depth of 12-18 inches, and VS-1C from 18-24 inches. At VS-3, sample VS-3A was taken from the surface, and VS-3B from a depth of 14-28 inches. The other samples were taken from the surface. The ash samples at VS-1, 3, 4, 16, and 17 were taken with the bucket auger; the others were dug with a shovel.

4. Sample Preparation and Analyses

All of the water samples were kept on ice, and within 24 hours of collection, one of the two 500 ml portions of each sample was prepared for metals analysis. Each of these samples was filtered through a 0.45 micron filter and fixed with 5 ml of nitric acid.

Fly ash samples Ph-6 and Ph-7 were sent to Lancaster Laboratories, Inc., Lancaster, Pennsylvania, where they were analyzed for total aluminum, arsenic, chromium, and selenium. The samples were prepared by acid digestion according

Figure 6
Off-Site Surface Water Sampling Locations

V-19—Sampling location
Scale: 1" = 2000'

Figure 7
Fly Ash Sampling Locations

VS-1—Sampling Location

Scale: 1" = 400'
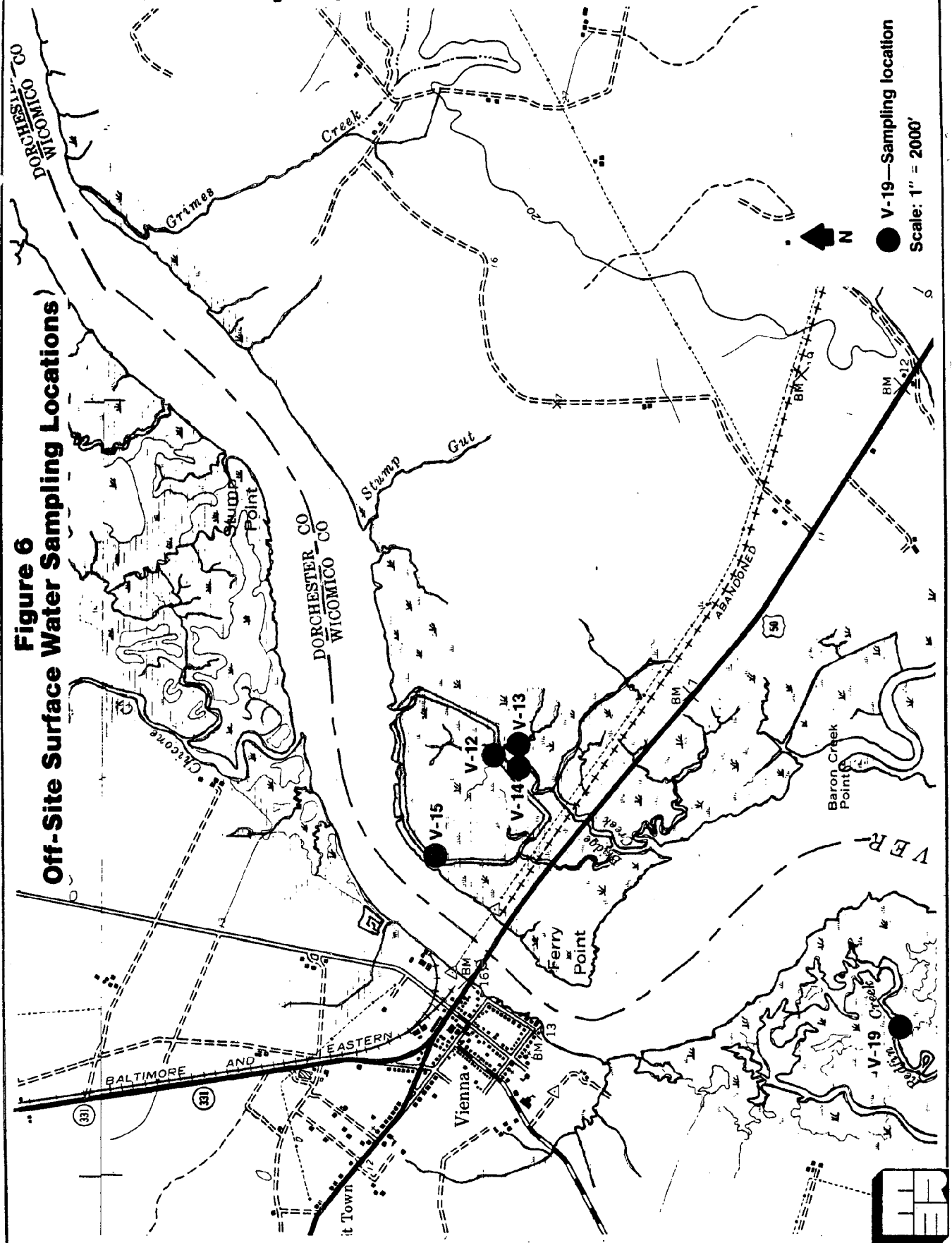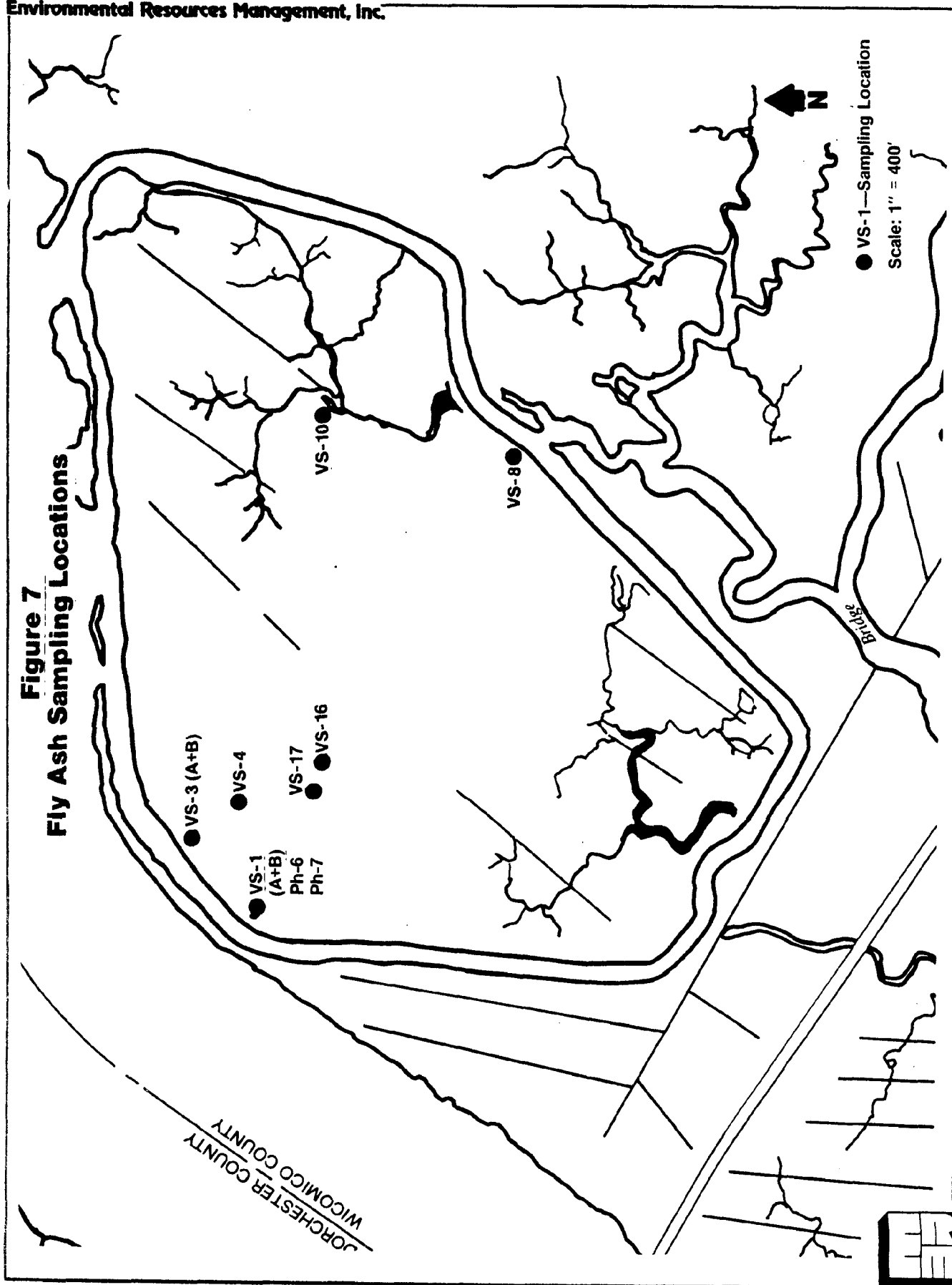
to the American Association of Analytical Chemists (AAOAC)
Method 2505 (AAOAC Manual, 12 edition) and the Parr Bomb
procedure (Journal of AAOAC, Vol. 55, 1972, p. 741). The
other fly ash samples were split, and a sample, labeled
VS-18, was composited from them. All of the fly ash and
water samples were sent to Lancaster Laboratories for
analysis.

In order to characterize the mobility of chemical constitu-
ents from the fly ash, and its potential environmental ef-
fects, ground water sample V-1 and composite fly ash sample
VS-18 were subjected to detailed analysis. The remaining
samples were held pending the results of these analyses.
Sample VS-18 was leached, and the leachate analyzed accord-
ing to U.S. EPA EP Toxicity determination procedures. This
was done in order to leach the sample at low pH conditions
to place into solution any potentially mobile heavy metals.
Both VS-18 and ground water sample V-1 were analyzed for pH,
total dissolved solids (TDS), chloride (Cl), sulfate (SO_4),
arsenic (As), barium (Ba), beryllium (Be), boron (B), cad-
mium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb),
mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), and
strontium (Sr). After the results of these analyses were
reviewed, the balance of the samples were analyzed as follows:

- Samples V-3, V-6, V-11, V-13, and V-19 - ana-
  lyzed for pH, TDS, SO_4, Cl, Ag, As, Ba, Be, Cd,
  Cr, Cu, Fe, Pb, Hg, Se, and Sr.

- Samples V-2, V-4, V-5, V-7, V-9, V-12, V-14, V-15 - analyzed for pH, TDS, Cl, SO_4, As, Ba, Cr, and Pb.

- Samples VS-1A, VS-1C, VS-3A, VS-3B, VS-8, VS-10 leached according to EP Toxicity Methods, and the leachates analyzed for pH, TDS, Cl, SO_4, As, Ba, Cd, Cr, Pb, and Se.

C. Results and Discussion

1. Fly Ash Distribution

The general distribution of fly ash inside the berm which surrounds the site is shown in Figure 8. The fly ash spread out across the site from the northwest corner area, where the slurry pipeline ended. It now forms a broad band trending southeast across the site to the eastern berm. A 5 to 10 inch deep root mat has formed in the fly ash, and a 1 to 2 inch thick organic layer occurs on top of most of the fly ash. The organic layer thins to nothing to the north and east. The fly ash thickness appears to be fairly uniform, at about 1 foot, except for a limited area near the end of the slurry pipeline. In this area the ash is about 3 feet thick. The fly ash deposit near the pipe terminus creates a dry area about 7 acres in extent (Figure 5). The fly ash deposit thins eastward as shown by the isopach contours in Figure 8. The entire area of concentrated fly ash deposit covers about 40 acres. With the thickness averaging about 1 foot, there are approximately 65,000 yd^3 of fly ash in the band.

**Figure 8
Fly Ash Distribution**

Flyash at or near land surface

Flyash grading to soil

Flyash grading to soil, with
areas of concentrated flyash

Flyash deposit under 1 ft
of topsoil

Flyash isopach (dashed
where inferred)

Flyash deposited in
surface drainageways

Scale: 1" = 400'

N

DORCHESTER COUNTY
WICOMICO COUNTY

Bridge
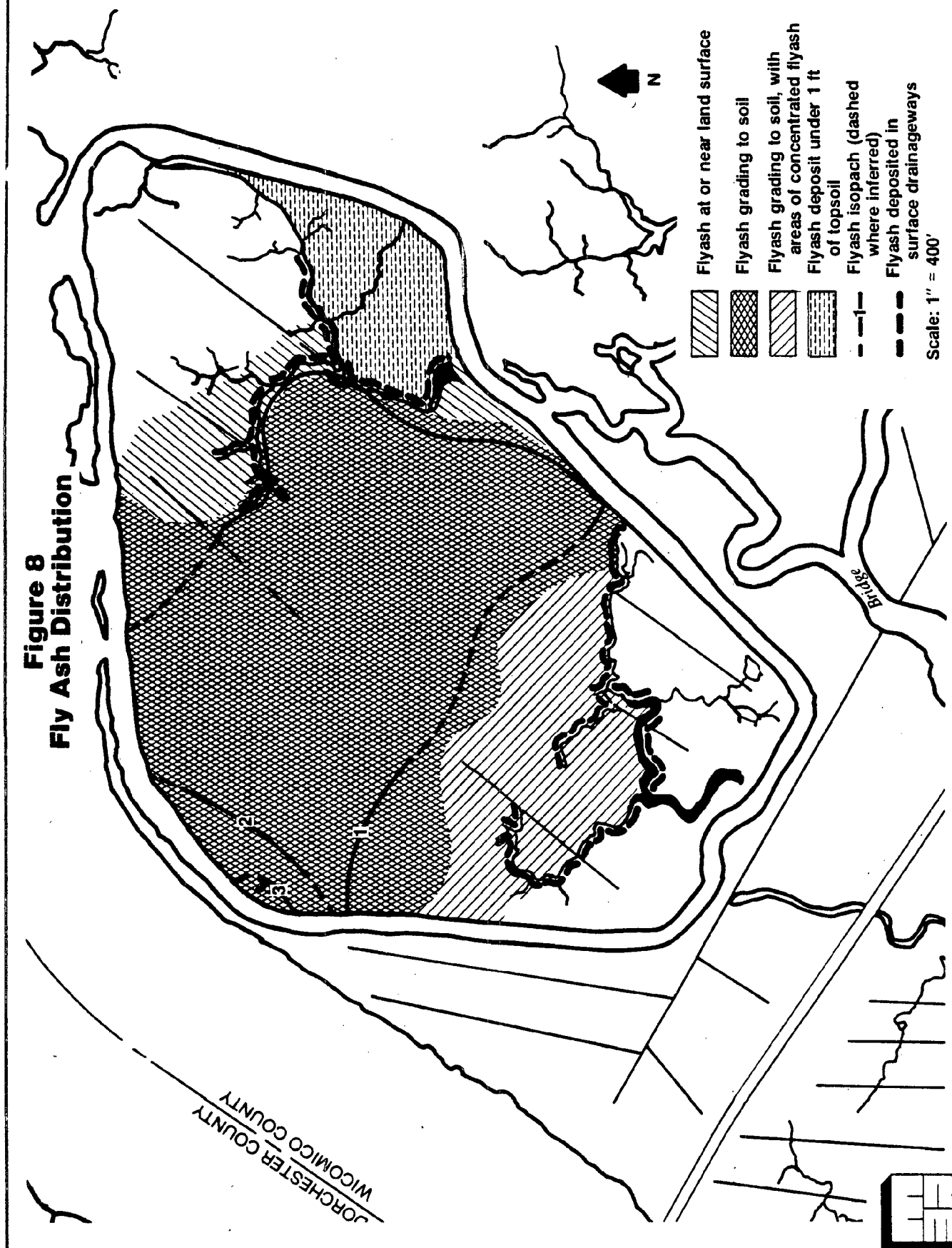
To the northeast, the fly ash extends to the main channel of the internal site drainageway. Northeast of the stream, the fly ash is present only as a fine sandy fraction in the silty soil, quickly diminishing in percentage to the northeast. The bed of the stream consists of a thick deposit of fly ash and some bottom ash (gravelly). The thickness of this fly ash, coupled with its absence immediately to the northeast, indicates that the movement of fly ash to the northeast terminated at the stream. The fly ash fraction in the soil northeast of the stream was probably deposited during flood stages of the stream.

The small eastern piece of this northeastern section of the site, east of the main stream channel and south of the westward flowing tributary, contains a layer of fly ash buried under approximately 1 foot of silt.

In the southern part of the site, the fly ash deposit extends to the two east-west tributaries which joined to form the main channel of the south flowing original drainageway. In this section, the fly ash deposits are erratic, with fly ash present in some areas and absent in others. This is the result of erosion of the original fly ash deposit which was carried southward, into the site streams. These stream beds contain fly ash deposits, often buried under silt.

2. Surface Drainage and Topography

Before construction of the berm and the surrounding moat and disposal of the fly ash, the site was drained by two south-flowing and one east-flowing tributaries to Bridge Creek

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(Figure 2). Only minor surface drainage had developed north-
ward and westward, toward the Nanticoke. This unusual drain-
age pattern can also be found in other tidal marshes occupy-
ing the insides of meanders on the Nanticoke. It appears
that this drainage pattern is superimposed by the incoming
tides, as the tidal marsh silts are deposited.

From comparison of pre-disposal and post-disposal aerial
photographs (as depicted in Figure 2 and Figure 3), it can
be seen that construction of the disposal site and deposi-
tion of the fly ash caused considerable changes in the site
drainage. The construction of the berm blocked off all
three drainageways. The disposed fly ash filled in the stream
channel of the eastward flowing stream at the center of the
site and small headwater tributaries of the other streams.
The main streams were also partially filled with fly ash.
The fact that the two present stream channels closely resemble
the original ones indicates that these channels were not
completely filled by fly ash. When the berm was breached,
the incoming tides followed the original stream channels
once again, and the original drainage pattern was maintained.
The breach of the berm at the mouth of the northernmost site
drainageway allowed the natural drainage to be reestablished.
However, the southern stream is still cut off by the berm.
It now discharges through breaches in the eastern berm,
through what were once its eastern headwater tributaries.

The disposal of fly ash created a topography which includes
a higher seven-acre dry area in the northwestern corner of
the site (Figure 5). From this high area, the topography

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slopes gently downward in all directions into the lower
swampy area. The surface drainage flows northeast and
southwest from a central divide. The total relief on the
site is about 5 to 10 feet.

The amount of erosion evident in the southern part of the
site indicates that fly ash has been leaving the site via
the stream. Tidal flushing through the breaks in the berm
allows fly ash to be carried in suspension into the moat.
This phenomenon has also been occurring in the northern
drainageway, where small tributaries to the main channel
from the central section of the site are cut into fly ash.
The fly ash deposit was originally thicker in this northern
area and more continuous than elsewhere on the site.

The extent of deposition of fly ash in the moat and con-
nected surface drainageways is unknown. A fly ash deposit a
few inches thick was observed in the mudflat beside the
eastern berm during low tide. The black, granular character
of the fly ash is very distinct from the brown silt of the
mudflat, rendering such distinction possible.

   3. Stratigraphy

The shallow stratigraphy at the site was determined from the
auger borings. Logs of these borings are included in Appendix
D. Eighty percent of the surface of the disposal area is
covered by a fly ash deposit up to 3 feet thick. This deposit
is completely overgrown with a stand of Phragmites, with a
mat of organic matter at the soil/air interface. Under this
fly ash deposit lies a buried marsh mat sequence, with thin
interbeds of running silt. The marsh mat is composed of

dense, decaying organic matter in a matrix of clayey silt.
The organic fraction ranges from greater than 50 percent
near the surface to absent at a depth of about 9 to 12 feet.
Approximately 7 feet of dark brown silt, containing no organic
fraction, underlies the swamp mat. This unit is extremely
unstable and precluded the installation of well points in
most of the borings. In boring V-1, some plastic clay and
clayey silt interbeds were encountered, which allowed the
installation of a well point. Under the silt is a unit of
subangular medium to coarse grained poorly sorted, light
colored quartz sand, with some fine non-quartz gravel. Near
the contact with the silt, the sand unit is very silty. The
silt fraction disappears quickly downward, leaving the sand
very clean. By comparison with boring logs from the Vienna
power plant area across the Nanticoke River (Delmarva Power,
1979), this unit has been identified as the Beaverdam facies
of the Pleistocene Salisbury Fm.

The dense root mat unit is essentially "floating" on the
runny silts. During the installation of the hand auger
borings, the augering activity could be felt underfoot as
the marsh mat moved. The running silts were forced upward
in the auger borings by the weight of the overlying marsh
mat. Log decriptions of all borings are included in Ap-
pendix D. Figures 9 and 10 show a geologic cross section
along the axis of the fly ash deposit.

Figure 9
Borings for Geologic Cross Section

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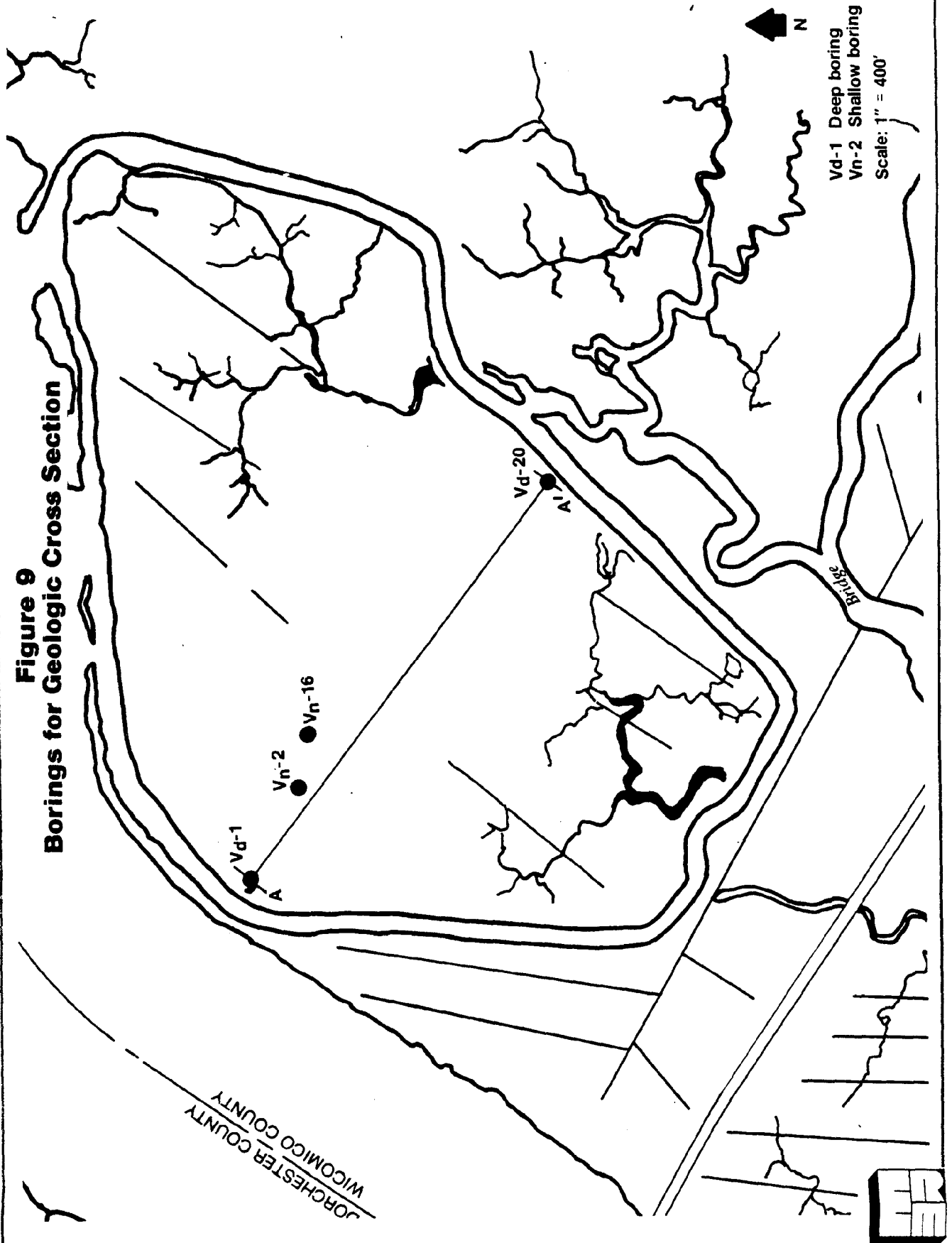
Figure 10
Geologic Cross Section—
Vienna Fly Ash Disposal Site
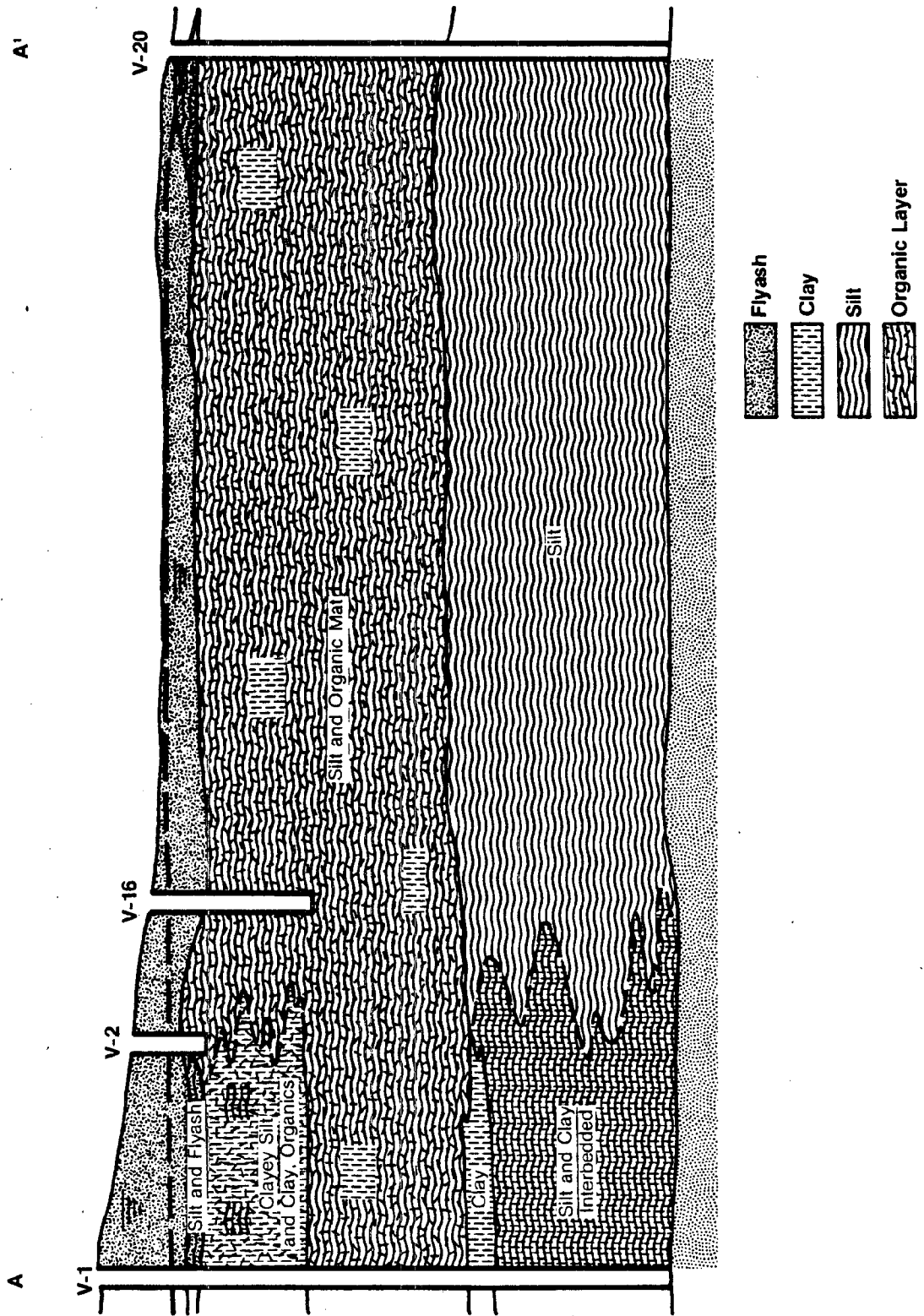
4. Hydrogeology

Because it was not possible to install well points and piezom-
eters throughout the site, specific hydrogeologic conditions
could not be quantified. However, certain significant con-
clusions can be drawn, based on the results of the hydrogeo-
logic studies which were conducted across the river at the
Vienna power plant (Geraghty and Miller, 1980) and on obser-
vation of conditions at the fly ash disposal site.

The disposal site occupies a tidal marsh which is connected
hydraulically to the river and is a zone of ground water
discharge. Ground water in the Pleistocene Salisbury aquifer
is moving from east of the site toward the river and dis-
charges to the river and the tidal marsh. It is probable
that this ground water enters the silt deposits beneath the
tidal marsh, eventually discharging to the river, mixed with
tidal inflow waters. A generalized geologic cross section
of the disposal site, the river, and the western bank of the
river near Vienna is shown in Figure 11.

Studies at the Vienna plant site determined that the ground
water in the Pleistocene aquifer tends to move horizontally
toward the river (Geraghty and Miller, 1980). This is re-
flected in the piezometric surfaces at various depths within
the aquifer. There is a slight downward head separating
these piezometric surfaces, but not significant enough to
effect detectable downward vectors in the vertical flow net.
Slight deflection of the vertical piezometric isopleths
shows a minor downward flow vector from the sands at the
surface through the Walston Silt, wherever it is present.
This is due to the effect of the Walston confining the under-
lying Beaverdam Sands in some areas. At the Vienna plant

Figure 11
Generalized Geologic Cross Section—
Vienna, Maryland; Nanticoke River & Marsh System

B

Delmarva Boring #101

Boring V-1

Boring V-20

B'

Flyash

Marsh Mat

River Channel Silt

Beaverdam Facies

Nanticoke River

Walston Silt

Red Gravelly Facies

St. Mary's FM

SALISBURY FM

Sand

Sand and gravel

Clay

Silt

Organic Layer

Scale: Horizontal 1" = 400'
Vertical 1" = 25'

N

Fly Ash Disposal Area

B'

B

Vienna Power Plant

BM 16

Ferry

ERM

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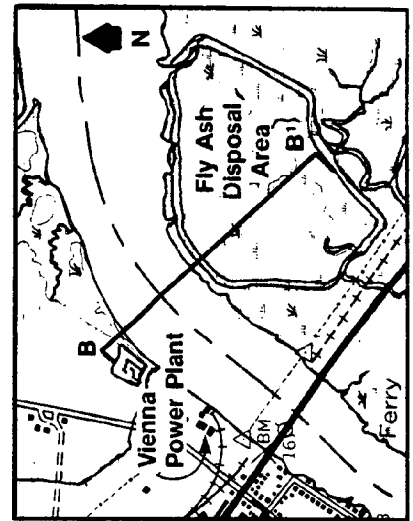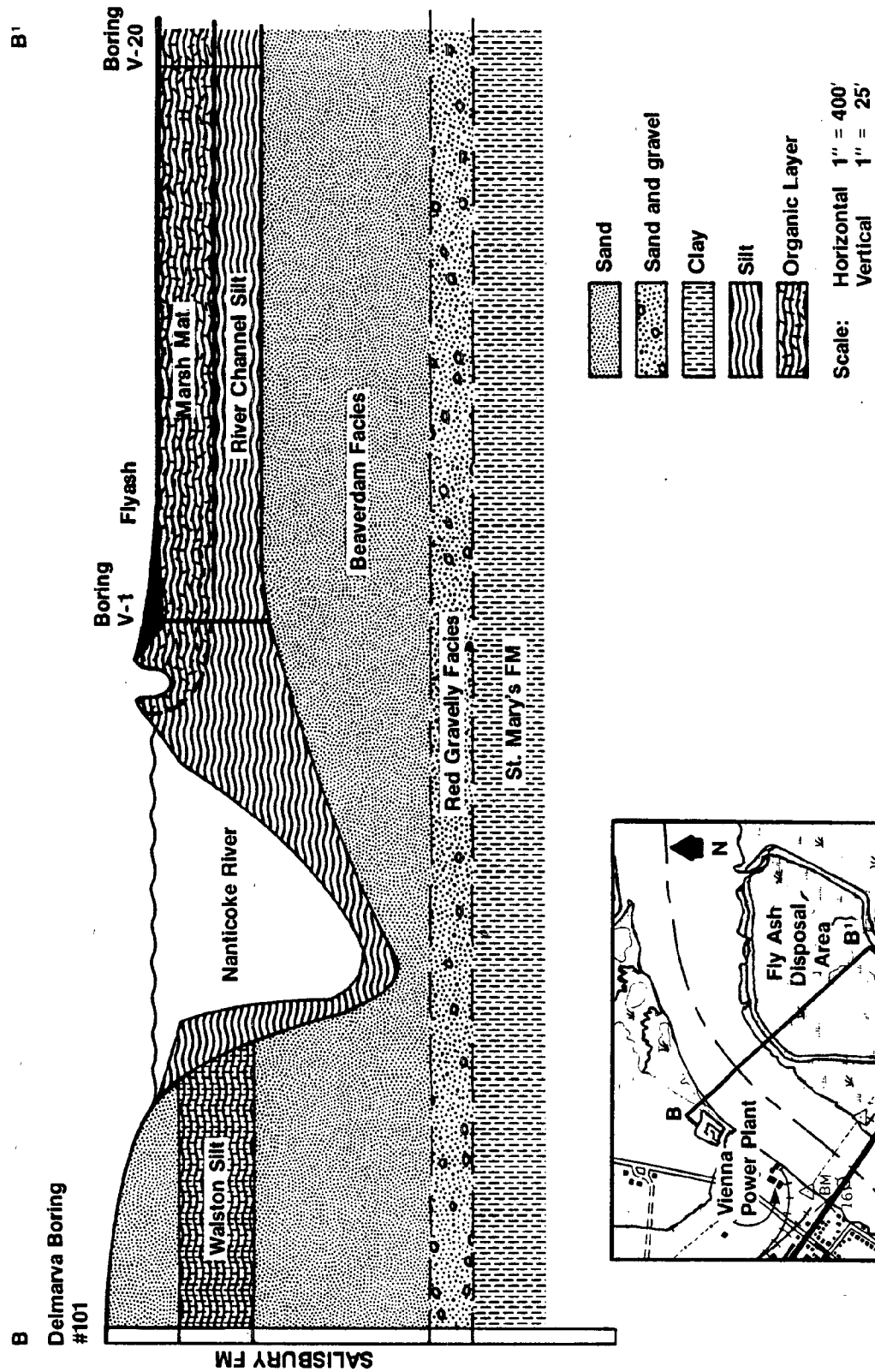
site, the Walston Silt occurs between elevations 0+ feet and
about -25 feet. Its discontinuous areal distribution and
variation in thickness do not allow it to be projected ac-
ross the river without boring logs. Therefore, it is un-
known whether this unit is present beneath the disposal
site. Since the unit occurs mostly above -20 feet in ele-
vation, it may be absent under the site due to either non-
deposition or river erosion.

Whether leakage occurs from the Salisbury Fm. to the under-
lying Calvert and Piney Point aquifers is unknown. However,
the presence of the thick St. Mary's Fm. aquiclude precludes
major recharge of these aquifers from the surface. There-
fore, local surface influences on ground water quality are
unlikely to be reflected in the water quality in the deeper
aquifers.

It is doubtful that the runny silt beneath the disposal site
confines the underlying Beaverdam sands. It is probable
that the Beaverdam ground water discharges to the tidal
marsh, or that the marsh and the Beaverdam act as one unit
in hydraulic equilibrium.

Since the disposal site is on a tidal marsh, the surface of
much of the site is at the level of the ground water table.
The dry area built up by the fly ash disposal, and other
small dry areas interspersed over the site, are the only
areas where ground water and surface water are not contigu-
ous. The surface streams draining the site might suggest a
ground water system with substantial discharge within the
site confines. However, these streams appear to be tidal
features rather than ground water discharge areas. At low
tide, these streams are reduced to a trickle. Since these

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streams are shallow (about 1-4 feet deep), they are devel-
oped in the swamp mat unit. Any ground water discharge from
this dense unit would be very slow, as is evidenced by the
failure of a ground water discharge to support low tide
flows in the site streams. Therefore, the water in the
streams can be considered to reflect mostly tidal inflow,
with a minor contribution of waters originating on site.

Water level measurements taken in Well V-1 confirm that the
ground water levels in the disposal areas are influenced by
the tidal action. A water level measurement taken at high
tide was 0.75 inches higher than one taken several hours
later, as low tide approached. This indicates that the
water beneath the marsh surface experiences regular ebb and
flow as the tides change. It is not known how deep in the
ground water system this effect persists. In the shallow
ground water, the effect is probably a lengthened residence
time of non-tidal waters in and near the fly ash.

Ultimately, the ground water flowing through the site dis-
charges to the Nanticoke River either directly or via the
moat. This discharge occurs principally through the silts
directly to the river, rather than via the on-site surface
streams.

Of the precipitation which falls on the 40 acres of the site
where the main fly ash deposit lies, most of this is lost by
runoff and evapotranspiration in the wet marsh area. The
runoff has limited contact with the fly ash due to the pres-
ence of the overlying organic mat. That water which does
recharge the limited dry area as ground water moves through
the fly ash in the shallow saturated zone, and discharges
radially outward from the dry area to the marsh.

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5. Fly Ash Analysis

Results of acid digestions of fly ash samples from the area
of the slurry pipe terminus are presented in Table 4.   These
analyses show that the fly ash in this area contains Al, As,
Cr, and Se.   The average Cr and Se levels here are close to
average levels for fresh fly ash from 23 locations in the
United States (Furr et al., 1977), as illustrated below.

Element	Literature Review Fresh Fly Ash Average	Vienna, Maryland Site Fly Ash Average
As	115.8	69.4
Cr	131.7	147.5
Se	8.4	5.9

The As levels in the fresh fly ash study showed a much greater
variation around the mean than did the chromium and selenium
levels.   Therefore, the current arsenic level at the site
may be due more to a low original concentration than to
leaching.   Overall, the site fly ash samples contained mod-
erate concentrations of metals, despite the age of the fly
ash and its exposure to leaching conditions.

The results of the fly ash leaching tests are presented in
Table 5.   Since a major concern is the effect of the disposal
site on potable ground water, the analyses are compared to
the U.S. Environmental Protection Agency's Interim Primary
Drinking Water Standards (PDWS) and Secondary Drinking Water
Standards (SDWS).   Composite sample VS-18 did not leach any
significant concentrations of TDS, Cl, SO_4, or metals.   How-
ever, the initial pH was less than 5, and the sample re-
quired no addition of acid for the EPT analysis.   Of the

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Table 4

Concentrations (ppm) of Trace Metals in Upper
15 cm of Ash Material from Vienna, MD
(Stations Identified in Figure 14)

Station	Al	As	Cr	Se
Ph-6	20,000	10.4	93	1.74
Ph-6	9,700	10.2	175	1.6
Ph-7	57,300	84.1	149	8.41
Ph-7	53,000	75.0	128	6.88
Mean	35,000	44.9	136	4.67

TABLE 5
FLY ASH LEACHING AND PCB ANALYSIS RESULTS
(Results in mg/l Unless Otherwise Noted)

Sample No.	Date	PCB	O.I(%)	TDS	Cl	SO4	Ag	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Sr
VP-1	11/4/81	<.2	.05																	
VP-2	11/4/81	<.2	.04																	
VP-3	11/19/81	<.5																		
VS-1A	11/12/81			158	1	84		<		<		<	<					.1*	<	
VS-1C	11/12/81			2080*	19	1020*		.009		<		<	.07*					<	<	
VS-3A	11/19/81			363	73	33		<		<		<	<					<	<	
VS-3B	11/19/81			251	52	72		<		<		<	<					.15*	<	
VS-8	11/19/81			337	153	39		.056*		.1		<	<					<	.007	
VS-10	11/19/81			597*	191	32		.005		<		<	<					<	<	
VS-18	Composite			183	56	46	<	<	<	.1	<	<	<	<	<	<	.2	<	<	.4
Detection Limits				na	na	na	.01	.004	40	.1	.005	.005	.05	.03	.05	.001	.05	.05	.004	na
Primary Drinking Water Standard (PDWS)							.05	.05		1.0		.01	.05			.002		.05	.01	
Secondary Drinking Water Standard (SDWS)				500	250	250														

< = less than detection limit
Blank = not run or no EPA standard
* = in excess of PDWS or SDWS

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metals, Ni, Sr, and Ba leached in detectable, but insignifi-
cant, amounts. Only Ba appears on the list of Primary Drink-
ing Water Standards used by the Environmental Protection
Agency (Table 5). The 0.1 mg/l in the fly ash leachate is
well below this standard.

The individual fly ash sample leachings showed a variety of
results. Sample VS-1A leached 0.10 mg/l of Pb, twice its
PDWS. Sample VS-1C leached 2,080 mg/l TDS, 1,020 mg/l SO_4,
0.009 mg/l As, and 0.07 mg/l Cr, all except As in excess of
their standards. Sample VS-3A leached moderate amounts of
TDS and Cl only. Sample VS-3B leached low TDS, Cl, and SO_4,
and 0.15 mg/l Pb. Only the Pb concentration is in excess of
its standard. Sample VS-8 leached moderate to low TDS, Cl,
and SO_4. Arsenic was slightly above and the Se just below
PDWS. Sample VS-10 leached 597 mg/l TDS, slightly in excess
of SDWS. Chlorides were moderate, and As was detectable but
below the PDWS. The pH's on all samples were below the min-
imum SDWS, with four below pH 5.

The leachability of various heavy metals from fly ash is
well documented in the literature (Roy et al., 1981). Maxi-
mum leaching of many metals occurs with lower pH conditions.
Thus, acidic fly ashes will tend to release metals more
readily than neutral or alkaline fly ashes. The 1980 De-
partment of Energy/ASTM study showed that leachates made
acidic by the ASTM-B and EPT test methods leached As, Cr,
Pb, Se, and Cd, sometimes at levels exceeding their PDWSs.

The pH levels for different fly ash leachates vary greatly
(Roy et al., 1981). However, studies to date show that the

pH of alkaline fly ash leachates generally decrease signif-
icantly with age, as the calcium is leached. The low pH
results for the site fly ash leachings indicate that the
original fly ash was probably a neutral to moderately acidic
material. Thus, the low pH conditions were probably estab-
lished early in the life of the site.

The low pH of the study site fly ash leachate creates fa-
vorable conditions for the mobilization of metals. Yet the
leachate analyses detected only very low levels of a few
metals. Therefore, it appears probable that the fly ash has
been leached of most of its available soluble metals in the
years since disposal ended. This is supported by the ab-
sence of Fe in the composite sample VS-18, since Fe would
conversely be expected in mg/l concentrations in fresh fly
ash leachate. Since the leaching of metals appears to have
progressed so far, the mobile species of metals originally
present cannot be determined. Arsenic seems to be the prin-
cipal metal currently leaching from the fly ash, albeit at
generally low levels. From comparison of the acid digestion
results (Table 4) and the leaching results from VS-1A and
VS-1C, it is noted that only very limited quantities of the
As, Cr, and Se remaining on site in the fly ash are mobile
from the fly ash via solution in natural waters.

The leaching of Pb from fly ash Samples VS-1A and VS-3B did
not appear to establish a meaningful pattern. VS-1A was
collected from above the water table, and VS-3B from below
it. In each case, a fly ash sample taken from the same
boring did not leach detectable Pb. Therefore, it is con-
cluded that these results represent localized occurrences of

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fly ash containing leachable Pb. Other such areas may exist on the site, and Pb may have been a significant site contaminant in the past.

Sample VS-1C leached substantial concentrations of TDS and SO_4. These constituents commonly leach in concentrations in the thousands of mg/l from fresh fly ash. Since sample VS-1C was collected from a depth of 2 feet in the area of thickest fly ash deposition, the leaching test probably indicates that some constituents have been carried from the upper fly ash into the VS-1C horizon. Also, since this sample was collected above the ground water table, lack of constant contact with ground or surface water has resulted in less leaching of this horizon. For comparison, even though Sample VS-3B was collected from near the 2 foot depth, it is still low in leached constituents. This sample was in constant contact with the ground water, unlike VS-1C. Thus, the age of the site fly ash is attested to by the generally moderate to low levels of these parameters in the leachates from six of the seven site samples. Most of the fly ash deposit is in constant or almost constant contact with ground and surface water and, therefore, has been leached of most constituents.

6. <u>Background Water Quality</u>

Since the study site is located in a tidal marsh, background water quality reflects brackish estuarine conditions. Surface water Samples V-13 and V-19 (Table 6) show typical background values to be about 6,000 mg/l TDS, 3,200 mg/l Cl, and 400 mg/l SO_4, with detectable Ba, Fe, and Sr in both and detectable Ag in V-19 and Cu in V-13.

TABLE 6
SURFACE WATER QUALITY ANALYSIS RESULTS
(Results in mg/l, Except pH in pH Units)

Sample No.	Date	TDS	Cl	SO₄	Ag	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Pb	Se	Sr	pH
V-5	11/19/81	5970	2950	384		.005	.3	<	<	<				<			6.60
V-6	11/19/81	6510	3200	415	.01	<	.2	<	<	<	.05	.21	<		<	1.4	6.61
V-9	11/19/81	5750	3300	368		<	.3			<				<			6.63
V-11	11/19/81	6280	2700	379	.01	<	.3	<	<	<	<	1.04	<	<	<	1.4	6.54
V-12	11/19/81	7690	3550	477		<	.2			<				<			6.92
V-13	11/19/81	6250	3200	409	.01	<	.2	<	<	<	.05	.13	<	<	<	1.4	6.67
V-14	11/19/81	6530	3500	464		<	.2			<				<			7.02
V-15	11/19/81	6690	3450	446		<	.2			<				<			6.9
V-19	12/10/81	6040	3200	421	.01	<	.2	<	<	<	<	2.49	<	<	<	1.4	7.17
PDWS					.05	.05	1.0		.01	.05			.002	.05	.01		
SDWS		500	250	250													6.5-8.5

< = less than detection limit

Blank = not run

* = at or in excess of PDWS or SDWS

Note - all TDS, Cl, SO₄ in excess of SDWS, due to estuarine environment

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Chemical equilibrium in sea water maintains an SO_4 to Cl ratio of about 0.13 (personal communication, Lancaster Laboratories). The values for V-13 and V-19 are 0.128 and 0.132 respectively, which reflects a sea water chemistry. This ratio is used for comparison of the water at the disposal site with background measurements from off-site marshes because, being an equilibrium condition, it should vary less between ebb and flow tidal stages than the individual parameters would. Heavy metals analyses revealed consistent small background levels of Ba (0.2 mg/l), Ag (0.01 mg/l), and Sr (0.1 mg/l). Iron concentrations were variable.

The area of the study site is all in tidal marsh, which exhibits mixing of tidal estuarine waters with ground water. The deposition of the fly ash created some dryer land, in which actual ground water could be defined. However, the rest of the tidal marshes are surface water areas, where no shallow ground water exists separately from the surface waters. Therefore, no background ground water conditions were determined.

7. Ground Water Quality

In general, the ground water quality at the site reflects a combination of fresh ground water discharge from the Salisbury Fm., estuarine tidal waters, and fly ash leachate. The ground water analyses from the most concentrated area of fly ash deposit, in the dry area, reflect the leaching of the fly ash (Table 7). The pH values range from 3.06 to 5.88, in contrast to the surface water pHs of 6.6-7.02. These pH

TABLE 7

GROUND WATER QUALITY ANALYSIS RESULTS

(Results in mg/l Except for SpC in Micromhos and pH in pH Units)

Sample No.	Date	SpC	TDS	Cl	SO4	Ag	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Sr	pH
V-1	11/19/81		2480	1150	711	<	.011	<	.3	.3	<	.05*	.03	210	<	<	.23*	<	1.0	5.84*
V-2	11/19/81	5200	4550*	2250*	423*		<		<			<					<			5.73*
V-3	11/19/81	4700	5660*	1050*	2780*	.01	.013		<	.072	.007	.1*	1.02	56	<		.08*	<	6.1	3.06*
V-4	11/19/81	6600	5560*	1850*	460*		<		.2			<					<			5.88*
V-7	11/19/81	4600	3550*	2150*	191		<		.3			<					<			6.05*
Detection Limit			na	na	na	.01	.004	10	.1	.005	.005	.05	.03	na	.001	.05	.05	.004	na	na
PDWS				250		.05	.05		1.0		.01	.05			.002		.05	.01		6.5-8.5
SDWS			500	250	250															

< = less than detection limit

Blank = not run or no EPA standard

* = at or in excess of PDWS or SDWS

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results are consistent with the leaching results of the fly ash. The TDS, Cl, and SO_4 levels in the ground water samples are very high. These constituents are common in the leachates of most fly ash materials. However, the tidally induced fluctuations in Well V-1 indicate that the ground water is mixed with the estuarine water. Therefore, it is necessary to distinguish the effects of the fly ash from those of the tidal marsh environment. The following observations can be made:

a)   The TDS concentrations in the ground water are lower than in the surface water. This reflects a mixing of brackish tidal water with fresh water. The ranges and means are: 2,480 to 5,660 mg/l, mean 4,360 mg/l in the ground water; and 5,970 to 7,690 mg/l, mean 6,412 mg/l in the surface water. The lower TDS values for the ground water would be expected since the precipitation recharge to the ground water in the dry area would have very low TDS concentrations, as would any discharge from the Pleistocene aquifer sands below.

b)   The Cl concentrations in the ground water are lower than in the surface water; the ranges and means are: 1,050 to 5,660 mg/l, mean 1,690 mg/l in the ground water; and 2,700 to 3,550 mg/l, mean 3,114 mg/l in the surface water. Again, this is a reflection of dilution by precipitation recharge and possibly by Pleistocene ground water discharge.

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c) The SO_4 concentrations in the ground water
vary greatly, ranging from 191 to 2,780 mg/l,
with a mean of 913 mg/l. The high values are
from samples taken under the dryer part of the
site and from areas where fly ash is thickest,
at V-1 and V-3. The lowest value is from lo-
cation V-7, where most of the fly ash has been
eroded away. The SO_4 concentrations in the
surface water samples range from 368 to 477 mg/
l, with a mean of 418 mg/l. The SO_4/Cl ratio
mean is 0.76 in the ground water samples. This
is heavily weighted toward the SO_4 parameter
compared to the 0.13 mean for the surface water.
Rain water and the water in the Pleistocene
aquifer, which constitute much of the site
ground waters, are low in sulfates (Delmarva
Permit Application, 1979). Therefore, the vari-
ation in the range, and the high mean of the
SO_4 concentrations in the ground water, are prob-
ably due to the fly ash.

The results of the heavy metals analyses indicate that the
quality of shallow ground water under the site is slightly
affected by the fly ash. Sample V-1 contained Cr at the
primary drinking water limit, and Pb slightly in excess of
the limit. Several other constituents were detectable in
concentrations of relatively minor significance. Sample V-3
contained Cr and Pb slightly above PDWS limits, in addition
to other detectable constituents. As with the leaching an-
alyses, the high Pb concentrations were limited to the V-1
and V-3 sampling locations, thus appearing to represent
localized areas of Pb containing fly ash. The presence of
high concentrations of Fe and Cu at these two locations may

indicate that localized elevated concentrations occur within the fly ash deposit. The other ground water samples contained no metals in significant concentrations, although a small amount of As was detected in V-4.

Comparison of these analytical results with the data on metals acid digested from site fly ash samples (Table 4) indicates a residuum of elevated levels of immobile As, Cr, and Se in the fly ash, with very low to undetectable concentrations in the ground water. Since the low pH conditions in the ground water should favor mobilization of metals, it is apparent that the mobile portion of the metals in the fly ash has been mostly leached away. The acidity of the fly ash hastened this process. It does appear that moderate levels of sulfur are still leaching from the fly ash as sulfate. This promotes the formation of sulfuric acid, which is probably responsible for the persisting low pH conditions.

Since most of the leaching of the site fly ash occurred in the past, at some time the leachate may have contained elevated concentrations of heavy metals, mobilized under the low pH conditions. Since the tidal marsh is a ground water discharge zone, the leachate is expected to have discharged via the marsh to the surface water drainage, especially during inundations of the site by floodwaters. However, since the leachates are more dense than natural waters (due to the elevated dissolved ion content), a plume of polluted ground water may have migrated vertically from the site, as a result of the density contrast. The contaminant transport model prepared for the proposed fly ash landfill at the powerplant site employs leachate density as a variable parameter (Frind and Palmer, 1980). Results indicated that

leachate density would accelerate vertical pollutant trans-
port in the early years of the landfill. (The model was
applied to the sands of the recharging Pleistocene aquifer,
not the silts of the tidal marsh discharge area.) This
phenomenon appears to have occurred in a ground water dis-
charge area at a site evaluated in Tennessee (Tennessee
Valley Authority, 1980). Similar density gradient induced
migration at the study site would allow some metals to reach
the Pleistocene aquifer. Assuming that flows through this
aquifer are similar to those from the power plant site,
between 0.25 and 1 foot per day (Geraghty and Miller, 1980),
travel time for the eastern edge of the plume to reach the
river would be from 5 to 20 years.

The existence of the St. Mary's Fm. aquiclude in this area
precludes the vertical movement of significant amounts of
any contaminated ground water into the underlying Calvert
and Piney Point aquifers. Therefore, the fly ash disposal
site poses no threat to any ground water supply wells which
might use these deep aquifers.

8. Surface Water Quality

The surface water quality on and surrounding the site is
typical of tidal marsh conditions as seen in samples V-13
and V-19. Sulfate to chloride ratios are typical of the .13
ratio of equilibrium conditions in sea water. No surface
water sample varied from that value by more than .02, includ-
ing samples V-5, V-6, V-9, and V-11, which were collected
from the on-site streams. This tends to verify the observa-
tion that the streams are mainly a tidal feature, with
little ground water discharge. It also tends to indicate

that the fly ash in the stream beds has been leached of most of its SO_4, Cl, and TDS by the continuous flushing of the tides.

Small concentrations of heavy metals were detected in two of the on-site samples, V-5 and V-6. A low level of As was found in sample V-5; in V-6, Cu was detected. However, Cu was also detected in background sample V-13. Other metal concentrations detected were insignificant. The off-site samples from the moat and Bridge Creek contained no metals of any significance compared to background. Thus, a small amount of As is seen in the site surface drainage, probably from the contact of the tidal inflow with the fly ash. The levels of metals in the ground water are so low that concentrations in any ground water discharge to the streams would be diluted below detection levels by the tidal waters.

Upon leaving the site, any small amounts of metals leached into surface waters from the fly ash are diluted below the detection limits.

9. <u>Potential Effect of the Disposal Site on Ground Water Development for the Town of Vienna</u>

One of the expressed concerns regarding the fly ash disposal site is whether or not any contaminants reaching the Pleistocene aquifer might be drawn into public water supply wells planned by the Town of Vienna, across the river. Data presented in the 1979 Delmarva permit application address the extent of the effects of developing and using a new 400 gpm

well in the Pleistocene aquifer to supply proposed Unit No.
9 with water. These data were extrapolated to possible
usage of ground water by the Town of Vienna. Current water
usage in the Vienna area, including Rabbit Town, (excluding
any power plant usage) probably averages less than 10,000
gallons per day. Therefore, a public water supply well of
approximately 100 gpm would provide adequate service to the
town.

The transmissivity of the Pleistocene aquifer is about 55,000
gpd/ft in the area 1/2 to 3/4 mile west of the river, de-
creasing to about 16,000 gpd/ft near the river. A one year
distance/drawdown curve was developed for the proposed 400
gpm Unit 9 withdrawal, based on a transmissivity of 38,000
gpd/ft. (Delmarva Power, 1979). At this withdrawal rate,
the projected cone of depression developed a maximum estimated
radius of 4,500 feet, assuming no recharge. If recharge is
taken into account, the extreme case cone of depression
radius of 4,500 feet would not develop at the proposed Unit
9 pumping rate of 400 gpm.

A public water supply well for the Town of Vienna, pumping
about 100 gpm, would not develop a cone of influence which
would extend the 2,000 plus feet under the river to inter-
cept Pleistocene aquifer ground water under the tidal marsh
disposal site. If located very close to the river, de-
creased aquifer transmissivity might produce a cone of de-
pression which would cause induced infiltration of water
from the river. Any heavy metals contribution from the
disposal site to the river would be undetectable as a result
of dilution with large volumes of river water.

Data available from the Vienna power plant site indicate
that the ground water beneath the plant site exhibits ele-
vated values for TDS, sulfate, and some heavy metals (Del-
marva Power, 1979). The source of these dissolved constit-
uents was not addressed in the Delmarva Permit Application
but may be associated with on-site fly ash disposal and,
possibly, on-site coal storage.

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SECTION V

BIOLOGICAL INVESTIGATIONS

A. Field Methodology

   1. Sampling Strategy and Organism Selection

The objective of the sampling design was to sample repre-
sentatively the disposal site for selected indicator matri-
ces and to be able to compare mean trace metal concentrations
with similar data from reference sites. The three most im-
portant characteristics in selecting suitable reference lo-
cations were: 1) similar salinity regime in the riverine
environment, 2) surrounded by a fringing marsh wetland, and
3) area removed from any potential impact of the disposal
site. Sampling locations included: 1) the fly ash disposal
area, 2) a reference site on the Nanticoke River approximately
2 km upstream of the disposal area, and 3) a second reference
area on the Choptank River approximately 1 km above the
Dover Bridge (Figure 12).

The use of these two reference locations permitted statistical
comparison of disposal site parameters with background data
from a site on the same river and with an ecologically sim-
ilar location on a different drainage. Water chemistry pa-
rameters measured at each location to characterize the sites
included: pH, salinity, specific conductance, and alkalinity.
Because these factors are influenced by tidal activity, tem-
poral variation can occur over a relatively short period.
Therefore, the purpose of our measurement during a single
point in time was simply to establish that the sites were
essentially similar with respect to these parameters. The

Figure 12
Vienna Site Assessment & Control Locations
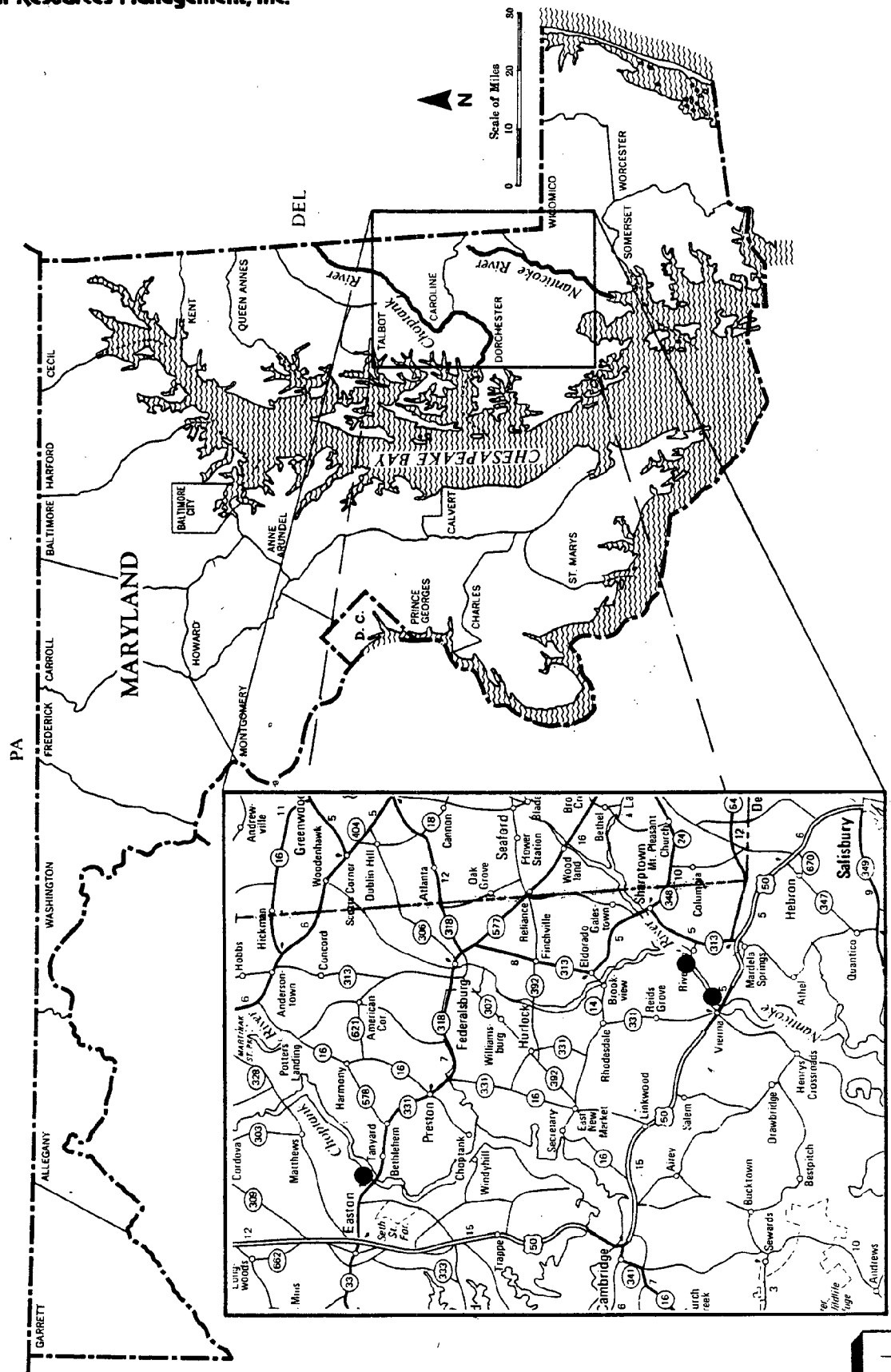
combined range for each parameter for the three sites is given in Table 8. For the purposes of this study, the three sites can be considered ecologically similar with respect to these basic water quality parameters.

Samples selected for examination included: 1) an aquatic emergent plant, arrow-arum, Peltandra virginica; 2) the predominant semi-terrestrial plant, Phragmites communis; 3) a benthic filter feeding clam, Rangia spp.; 4) an omnivorous fish species, mummichog, Fundulus heteroclitus; 5) a potential food fish species, white perch, Morone americana; 6) sediment samples; and 7) surface water samples. Five sampling stations were chosen for Peltandra, Fundulus, and sediment at each location. Water quality was sampled at four stations at each location. Phragmites rhizome samples were collected from the ash disposal site as this species was found to be growing directly on the ash material. White perch were collected from the Nanticoke River immediately adjacent to the disposal site to investigate trace metal levels in a representative food fish species. Sampling to determine the possible impact of the disposal area on the associated biota was conducted on 21-22 and 28-29 October 1981. Sampling stations at each of the three sites are shown in Figures 13, 14, and 15.

Sampling for Rangia spp. proved unsuccessful. Considerable effort was expended raking the substratum at various disposal site stations in an attempt to collect specimens. Although the species had been reported from the Nanticoke, only a very few specimens were collected from a single location. This lack of sampling success is consistent with the reported unsuitability of the sediment in the area for sup-

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Table 8

Combined Ranges of Selected Water Chemistry Parameters
as Sampled from the Three Study Locations

pH	Salinity (ppt)	Conductivity (umhos/cm)	Total Alkalinity (mg/l CaCO)
6.1 - 7.1	3 - 6	3,500 - 7,000	29.9 - 65.7

Figure 13
Plant, Animal, Sediment and
Surface Water Sampling Locations
at Disposal Site (Oct. 1981)

Legend

⬤ Plant, Animal & Sediment
Sample Locations and
Identification No.
(21-22 Oct. 81)

◼ Surface Water Sample
Locations & Identi-
fication No.
(28-29 Oct. 81)

▲ Phragmites Sample - (Ph)

Vienna

Vienna
Power Plant

NANTICOKE

RIVER

DORCHESTER COUNTY
WICOMICO COUNTY

Ferry Point

DORCHESTER
WICOMICO

Slurry Pipe

Navigation Blocks—
Pilings Across channel

Fly Ash
Disposal Area

Creek

Bridge

Scale: 1" = 400'

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Figure 14

Plant, Animal, Sediment and Surface Water Sampling Locations on the Nanticoke River (Oct. 1981)

Legend:
- Plant, Animal & Sediment Sample Locations and Identification No. (21-22 Oct. 81)
- Surface Water Sample Locations and Identification No. (28-29 Oct. 81)

Scale in Feet

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Figure 15
Plant, Animal, Sediment and Surface Water Sampling Locations on the Choptank River (Oct. 1981)

● Plant, Animal & Sediment Sample Locations and Identification No. (21-22 Oct. 81)

■ Surface Water Sample Locations and Identification No. (28-29 Oct. 81)

N

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Scale: 1" = 2000'
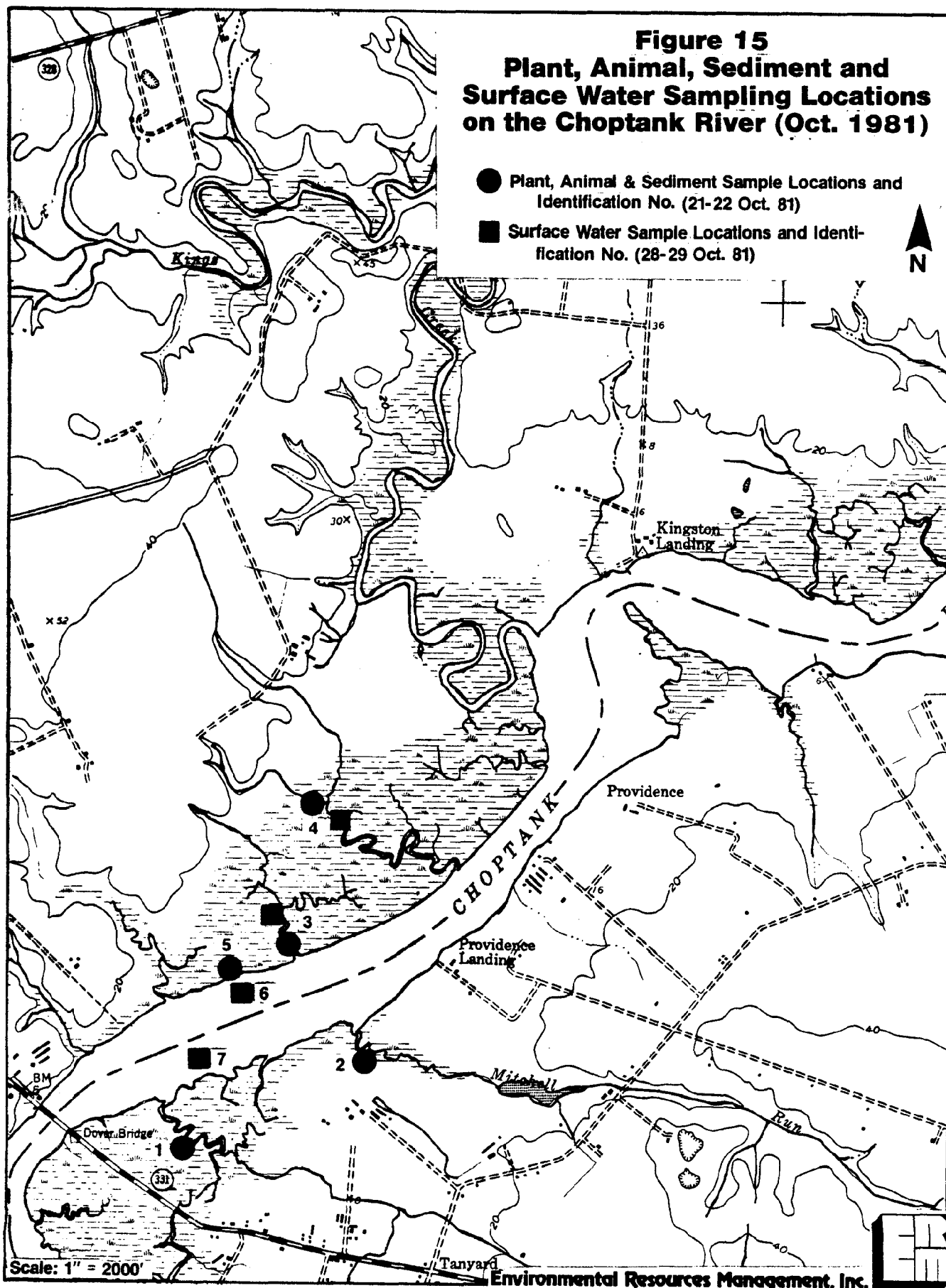
porting macrobenthic organisms (Portner, 1981). Local pop-
ulations of Rangia are apparently of low density and may be
broadly disjunct. Thus, the use of Rangia as a potential
indicator organism in this investigation would not be prac-
tical. Other pelecypods, such as the blue mussel (Mytilus),
do not occur in such low salinity (4-8 ppt) habitats.

2. Collection Program

Dip-netting was found to be an effective collection method
to obtain mummichogs (killifish), Fundulus heteroclitus, and
was utilized to collect all samples. Baited minnow traps
proved unsuccessful. A substantial effort was made to obtain
at least five specimens at each sampling station to produce
a more representative composite sample; however, this was
not always possible. Therefore, the number of specimens
comprising a given sample is provided in the RESULTS section.

White perch, Morone americana, were collected only in the
Nanticoke River adjacent to the disposal site, using fyke
nets. All five specimens were prepared for analysis by
removing the head, viscera, and scales to produce a sample
representative of fish prepared for human consumption. How-
ever, bones were not removed from these small specimens.
Scale analysis showed that all specimens were age I+. The
use of fyke nets and gill nets at the control locations
produced no white perch, possibly due to the fall migration
of M. americana out of the sampling areas (Delmarva Power,
1979).

The root mass and fruiting bodies of Peltandra were collected and analyzed to investigate the possibility of organ-specific bioaccumulation. Each sample was composed of a minimum of one complete root mass and at least one dozen seeds from one or more fruiting bodies. The root and seed samples collected at a given station were not necessarily from the same plant because the fruit pods had all ripened and fallen by the sampling date. Therefore, individual seeds were collected, in most cases, within the immediate area of root sampling to obtain specimens produced within essentially the same microhabitat conditions.

Phragmites rhizome samples were dug from the dense root mat established in the fly ash. Each sample consisted of approximately a half meter section of rhizome with associated dormant shoots.

Sediment samples were obtained at each of the five sampling stations at all three locations. A single sample of approximately 0.3 liter was collected from the upper 0.3 m at each station.

Water samples collected from the two control locations included two samples from tributary creeks and two samples from the river (Figures 14 and 15). At the disposal site, samples were collected at four locations from the stream and channel system which drains the site (Figure 13). All water samples were collected at the end of an ebb tide period in order to obtain water which had drained off the adjacent marsh.

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B.   Laboratory Methodology

Tissue and sediment field samples were placed in zip-lock
plastic bags, labeled, and immediately placed on ice. Be-
fore sending samples to Lancaster Laboratories, Inc. for
analysis, selected larger samples of killifish, arrow-arum
roots, and arrow-arum seeds were sorted into two whole-spec-
imen samples and relabeled to obtain an estimate of within
station variability. All plant samples were thoroughly
cleansed of soil and then rinsed in distilled water before
being sent out for analysis. Tissue and sediment samples
were dried at $100^{o}C$, homogenized, and subjected to a total
acid digestion prior to atomic absorption analysis.

Water samples were collected in half-liter polypropylene
bottles, placed on ice, and then transported to the
University of Delaware, College of Marine Studies (CMS) at
Lewes, Delaware. Water samples were acidified, filtered,
and analyzed using a Perkin-Elmer 603 atomic absorption
spectrophotometer equipped with a graphitic furnace. Mul-
tiple injections of samples provided an estimate of ana-
lytical uncertainty.

C.   Statistical Methods

Statistical analysis involved comparison of mean trace metal
concentrations using Wilcoxson's two-sample test for unpaired
observations (Steel and Torrie, 1960). This non-parametric
test was selected as it was uncertain that the assumptions
associated with applying a two-sample t-test (i.e., random
samples drawn from normally distributed populations with

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equal variances) were sufficiently satisfied. Therefore,
the distribution-free statistical test was selected. How-
ever, for additional insight, t-tests were also conducted on
all comparisons with virtually identical results. A summary
of the t-test results is provided in Appendix E.

D. Results and Discussion

1. Mummichogs, Fundulus heteroclitus

The results of the trace metal analysis on F. heteroclitus
collected at all three locations are shown in Table 9. Rep-
licate samples were collected at some sample stations to
obtain a qualitative estimate of the variation within a
station. The replicate results indicate that substantial
variability exists among fish collected in the same micro-
habitat. Concentrations of Al, As, and Se were signifi-
cantly greater (P < 0.05) in the killifish collected at the
disposal site than in killifish collected at the upstream
control locations. Mean trace metal concentrations were
also higher in disposal site specimens than in specimens
collected from the Choptank River location. However, in
this comparison, killifish from the disposal site possessed
significantly greater (P < 0.01) As levels, only. Mean con-
centrations of the other three metals (Al, Cr, Se) were
greater in the disposal site specimens (Table 9), although
the differences did not prove significant (P > 0.05).

The results indicate that killifish collected at the dis-
posal site had accumulated a significantly higher level of

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Table 9

Whole Body Trace Metal Concentrations in
Mummichogs, Fundulus heteroclitus

Stations	No. of Specimens in Sample (homogenized)	Per Sample Metal Concentration (ppm)			
		Al	As	Cr	Se
V-1	0	–	–	–	–
V-2	2	138	2.2	< 2	1.15
V-3	5	1900	1.8	3	2.93
V-3	5	3150	2.9	4	2.54
V-4	5	1670	2.1	3	2.49
V-5	5	2240	1.5	3	2.28
V-5	5	1350	1.0	2	1.70
Weighted Mean*	27	1920	1.9	< 3	2.30
N-1	5	58	< 0.5	< 1	0.71
N-1	5	38	< 0.5	< 1	1.06
N-2	5	388	0.5	< 1	0.77
N-2	5	68	0.6	< 1	0.90
N-3	5	186	< 0.5	< 1	1.03
N-4	3	65	1.2	4	0.89
N-5	0				
Weighted Mean	28	139	< 0.6	< 1	0.89
Ch-1	5	1860	< 0.5	2	2.27
Ch-2	2	5100	0.8	6	3.19
Ch-3	5	651	0.5	< 1	1.94
Ch-3	5	189	< 0.5	1	1.48
Ch-4	3	697	< 0.5	2	1.79
Ch-5	5	474	< 0.5	1	1.63
Ch-5	5	1200	< 0.5	2	1.64
Weighted Mean	30	1139	< 0.5	< 2	1.89

*Means were numerically weighted by the size of the sample.

trace metals than fish taken approximately 2 km upstream on
the Nanticoke River. Furthermore, the differences in metal
concentrations were approximately an order of magnitude for
Al and As and more than double for Se, resulting in highly
significant concentration differences $(P < 0.01)$. If it is
assumed that the killifish populations are highly localized
and, therefore, are primarily influenced by the environ-
mental quality of the immediate area, the results suggest
that a localized source of contamination may exist near the
disposal site which is affecting this resident fish species.
However, compared to the Choptank River specimens, only the
As concentration would suggest that a potential source of
contamination exists near the disposal site. Although com-
parison with the Nanticoke reference station specimens sug-
gests a possible pollution source at the disposal location,
the greater similarity among other metals between the dis-
posal site specimens and Choptank River reference specimens
imposes the need for cautious interpretation of the results.
However, there is some indication of a source of contamina-
tion on the Choptank River above the reference station which
likely influenced the samples (pers. comm. MD Dept. of Health).

2. White Perch, _Morone_ _americana_

The results of trace metal analyses on white perch taken
from the Nanticoke River near the disposal site are given in
Table 10. Unfortunately, the data cannot be compared to
similar information for the two control locations because
sampling efforts failed to produce white perch at the controls.
Levels of As and Cr were below detectable limits. The Al
concentration was also relatively low. The notably high Se

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Table 10

Trace Metal Concentrations in
White Perch (Prepared in the Round)
from the Nanticoke River Near Vienna Disposal Site

Metal	Tissue Concentration (ppm)
Al	5
As	< 0.5
Cr	< 1
Se	1.40

value may be largely attributable to the fact that a portion
of the skeletal system was included in the tissue sample,
and bone is a known accumulation site for trace metals (Dvorak
et al., 1978). These results are similar to those reported
by Guthrie and Cherry (1976) in examination of stream verte-
brates and invertebrates receiving fly ash settling-basin
effluent. Mean annual concentrations of virtually all trace
elements were reportedly lowest in fish with the exception
of Ca and Se. Also consistent with this evidence are the
findings of Mehrle et al. (1982) on contaminants of east
coast striped bass, Morone saxatilis. Se and As were shown
to accumulate in Nanticoke River fish from the riverine
environment. Furthermore, Se residues tended to increase
with the age of the fish.

This evidence suggests that Morone spp., and possibily other
Nanticoke River fishes, are capable of bioaccumulating Se
from the riverine environment. However, several factors

The U.S. EPA (1980), recognizing the potential for biocon-
centration, utilizes an average daily per capita consumption
of 6.5 g of freshwater and estuarine fish and shellfish to
estimate daily Se intake. The U.S. EPA also uses a 50 to
200 µg per day dietary intake of Se as being safe and ade-
quate for adults. Using the recommended 6.5 g fish per day
consumed, multiplied by the average fish tissue Se concen-
tration of 1.4 µg/g, results in a value of 9.1 µg per day
from consumption of Morone spp. captured at the Vienna site.
This value is relatively low compared with the recommended
EPA guidelines stated above.

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Several factors warrant cautious interpretation: 1) the inclusion of bone tissue in our white perch samples prevents comparison to EPA guidelines for safe consumption, 2) our data cannot be compared to results from the two control locations because sampling efforts did not produce the same species (white perch), and 3) the migratory nature of <u>Morone</u> spp. in this area complicates the determination of the source(s) and mechanism(s) of possible contamination.

3. Sediment

The results of the sediment analyses are shown in Table 11. No significant mean concentration differences ($P < 0.05$) were found between the Nanticoke reference site and the disposal site. The Choptank site was significantly higher ($P < 0.05$) in Al than the disposal site, and the disposal site was significantly higher ($P < 0.05$) in As than the Choptank site. The order of elemental abundance in sediment samples was the same for all three sites (i.e., Al> Cr> As> Se) and typical of concentration levels found in endogenous soils (Dvorak, 1978). This order of trace metal abundance was also found in the fly ash from the disposal site (Table 4). However, comparisons of the mean trace metal concentration levels between the fly ash samples and sediment samples from the Vienna disposal site (Table 11) were significantly different ($P < 0.05$) for Al and Cr. The Al concentration was greater in the sediment than the fly ash; conversely, the Cr level' was greater in the fly ash. Although the As and Se levels were substantially greater in the fly ash samples, the differences did not prove significant ($P > 0.05$). These differences between the fly ash and sediment at the disposal site suggest that the constituency of the sediment (in the areas sampled) is not predominantly fly ash material.

Table 11

Trace Metal Concentrations in Sediment Samples
of Tidal Streams and Disposal Site Moat

Station	Al (% dry wt.)	Metal Concentration(ppm)		
		As	Cr	Se
V-1	6.1	9.05	64	0.6
V-2	6.4	7.84	60	0.62
V-3	5.9	9.7	67	0.37
V-4	5.7	9.0	68	0.38
V-5	5.8	11.8	65	< 0.25
Mean	6.0	9.48	65	< 0.44
N-1	6.1	8.03	70	0.72
N-2	5.8	9.6	68	0.4
N-3	6.0	7.78	64	0.61
N-4	6.1	7.38	63	< 0.25
N-5	6.0	10.2	67	0.42
Mean	6.0	8.6	66	< 0.48
Ch-1	6.9	6.69	73	0.50
Ch-2	6.5	6.67	75	0.66
Ch-3	7.0	8.61	80	0.35
Ch-4	6.7	6.58	59	< 0.25
Ch-5	7.2	6.7	69	0.36
Mean	6.9	7.05	71	< 0.42

4.   Arrow-arum, <u>Peltandra virginica</u>

The results of the trace metal analyses on the roots and
seeds of <u>P</u>. <u>virginica</u> are shown in Tables 12 and 13, respec-
tively. Statistical comparisons of the rhizome metal levels
revealed significant differences (P < 0.05) between the Vienna
and Choptank sites for As and Se. Arsenic levels were greater
at the disposal site, while Se levels were higher at the
Choptank site. Similar comparisons of metal concentrations
in the seeds revealed a significantly greater (P < 0.01)
level of As in fruiting bodies from the disposal site than
from the Choptank River location. No significant differences
(P < 0.05) were found between the disposal site and the Nan-
ticoke reference site for root or seed sample comparisons.

Comparisons of trace metal levels were made between the
roots and seeds collected at each location to examine the
possibility of organ-specific bioaccumulation. The roots
possessed significantly higher (P < 0.05) levels of both Al
and As than the seeds for all three locations. Mean concen-
trations of Cr were also substantially higher in the roots
than in seeds; however, statistical significance could not
be determined because Cr levels in <u>all</u> seed samples were
below detectable values (Table 13). Comparison of Se levels
between roots and seeds revealed that mean concentrations
were not significantly different (P > 0.05).

Organ-specific bioaccumulation is further evidenced by com-
paring concentration ratios. The ratio of mean metal con-
centration in roots and seeds (Tables 12 and 13) to mean
concentration found in the sediment (Table 10) is provided
in Table 14. The results indicated substantial differences

Table 12

Trace Metal Concentrations in
Roots of Arrow-arum, Peltandra virginica

Station	Metal Concentration (ppm)			
	Al	As	Cr	Se
V-1	1820	2.13	6	< 0.05
V-2	632	5.43	4	0.07
V-2	403	3.09	3	< 0.05
V-3	705	1.50	2	< 0.05
V-3	1180	2.77	4	< 0.05
V-4	595	1.35	2	0.18
V-5	268	0.55	< 1	0.16
Mean	800	2.40	< 3	< 0.09
N-1	1260	1.47	5	0.06
N-1	1520	2.05	5	0.14
N-2	2400	4.81	16	< 0.05
N-3	391	1.09	4	< 0.05
N-4	386	0.49	2	< 0.05
N-5	384	0.32	3	< 0.05
N-5	344	0.30	7	< 0.05
Mean	955	1.50	6	< 0.06
Ch-1	575	0.35	3	0.12
Ch-2	505	1.28	3	0.22
Ch-3	850	0.65	3	0.16
Ch-4	734	0.80	2	0.18
Ch-4	782	0.75	3	0.16
Ch-5	345	0.33	2	0.11
Ch-5	310	0.28	2	0.21
Mean	586	0.63	3	0.17

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Table 13

Trace Metal Concentrations in Seeds
of Arrow-arum, Peltandra virginica

Station	Metal Concentration (ppm)			
	Al	As	Cr	Se
V-1 & V-2	34	0.15	< 1	0.12
V-3	20	0.18	< 1	0.10
V-3	108	0.27	< 1	0.22
V-4	46	0.13	< 1	0.13
V-5	14	0.14	< 1	0.10
Mean	44	0.17	< 1	0.13
N-1	36	0.15	< 1	0.21
N-2	46	0.51	< 1	0.11
N-2	28	0.10	< 1	0.07
N-3	< 2	0.10	< 1	< 0.05
N-4	262	0.22	< 1	0.17
N-5	11	0.10	< 1	0.12
N-5	9	0.14	< 1	0.09
Mean	< 56	0.19	< 1	< 0.12
Ch-1	3	< 0.05	< 1	0.09
Ch-2	23	< 0.05	< 1	0.06
Ch-3	53	0.10	< 1	0.11
Ch-4	24	0.08	< 1	0.22
Ch-4	57	0.11	< 1	0.30
Ch-5	25	0.10	< 1	0.16
Mean	31	< 0.08	< 1	0.16

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Table 14

Plant:Soil Concentration Ratios

Element	Concentration Ratio[a]	P. virginica Concentration Ratios		
		Roots	Fruit	Location
Aluminum		0.013	0.0007	Vienna
		0.016	0.0009	Nanticoke
		0.008	0.0004	Choptank
Arsenic	0.14	0.25	0.02	Vienna
		0.17	0.02	Nanticoke
		0.09	< 0.01	Choptank
Chromium	0.02	0.05	< 0.02	Vienna
		0.09	< 0.02	Nanticoke
		0.04	< 0.01	Choptank
Selenium	1.0	< 0.2	< 0.30	Vienna
		0.13	0.25	Nanticoke
		0.4	0.38	Choptank

[a]From Dvorak et al. 1978
This is a generalized approximation of the ability of plants
to accumulate trace elements similar to the method employed
by Hodgson. The concentration ratio is the ratio of the
average concentration of each trace element in plants to the
average concentration of each trace element in soils.

between seeds and root concentration ratios for Al and As
and, to a lesser extent, for Cr. The values for Se showed
no clear trend. These findings are essentially identical to
the results of the statistical comparisons.

In general, organ-specific bioaccumulation in P. virginica
appears to be consistent with the reported trend of roots>
stems and leaves> fruits or seeds (Dvorak et al., 1978).
This finding is generally encouraging since the root tissue
is less likely to be used as a food source than the fruit or
seeds, thereby reducing the potential for biomagnification
in animals. However, as these plant parts decay, these
metals may be available in the habitat for recycling or
transport.

5. Phragmites communis

Samples of Phragmites rhizome were taken at six stations
from the ash disposal site (Figure 13). The results of the
trace metal analyses are shown in Table 15. Mean relative
concentrations found in the rhizomes reflected the relative
concentrations of the four metals in the upper 15 cm of the
ash material (Table 4).

Relative concentrations of the elements were Al> Cr> As> Se.
This order of elemental abundance is also characteristic of
endogenous soil concentrations (Dvorak, 1978) and is commonly
observed in plant tissue.

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Table 15

Trace Metal Concentrations in
Rhizomes of Phragmitis communis

Station	Metal Concentration (ppm)			
	Al	As	Cr	Se
Ph-1	55	0.25	5	0.09
Ph-2	442	0.42	25	0.19
Ph-3	235	0.95	8	0.28
Ph-4	320	0.55	9	0.07
Ph-5	100	0.30	8	0.20
Ph-6	119	0.69	7	0.16
Mean	212	0.53	10	0.17

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6. Surface Waters

The results of the surface water analyses are provided in
Table 16. The average Se concentrations at all three loca-
tions exceeded the EPA criterion of 22 ug/l for protection
of freshwater aquatic life. This finding resulted in a
check of the original analysis utilizing a new Se lamp. The
second set of Se results were quite similar to the first
(Table 17). A review of sample preparation revealed that
the CMS laboratory had acidified the samples before filter-
ing, which is opposite of the standard EPA method for analy-
sis of dissolved metals (U.S. EPA, 1979). Therefore, metals
tied up in the suspended fraction would have been at least
partially dissolved upon acidification to pH 2. Thus, the
results of the analyses would be higher than the actual
dissolved trace metal concentrations.

The utility of these data is limited, especially in regard
to Se. The fact that these Se concentrations were greater
than EPA guidelines for dissolved Se does not necessarily
mean that the ambient dissolved Se concentration is a prob-
lem. The results of the surface water analyses conducted
during the hydrogeologic phase of this study, in which sam-
ples were not acidified first, indicate that dissolved Se
concentrations are within the prescribed EPA guidelines at
the disposal site (Table 6).

The recommended standards for protection of aquatic orga-
nisms for Al, As, and Cr are 63 ug/l, 130 ug/l, and 100
ug/l, respectively (Sittig, 1980). The observed mean con-
centrations of these metals, even though artificially in-
creased by the processing error, were within these guide-
lines. This is further evidenced by the results of the

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Table 16

Trace Metal Concentrations in Water Samples
from the Three Study Locations

Station	Metal Concentration (ppb)			
	Al	As	Cr	Se
V-6	100.0	39.7	< 1.2	30
V-7	55.6	54.1	1.4	21
V-8	44.4	37.4	< 1.2	29
V-2	47.2	34.4	1.6	34
Mean	61.8	41.4	< 1.35	28.5
N-1	55.6	31.5	< 1.2	26
N-2	50.0	37.1	< 1.2	34
N-6	58.3	32.7	1.4	31
N-7	65.0	33.5	< 1.2	27
Mean	57.2	33.7	< 1.25	29.5
Ch-3	61.1	39.3	< 1.2	58
Ch-4	50.0	35.6	< 1.2	58
Ch-6	61.1	40.7	< 1.2	57
Ch-7	61.1	43.2	< 1.2	57
Mean	58.3	39.7	< 1.2	57.5

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Table 17

Second Analysis of Selenium Concentration (ppm)
in Waters from the Three Study Locations

Choptank Control		Nanticoke Control		Vienna Site	
Station	Metal Conc.	Station	Metal Conc.	Station	Metal Conc.
Ch-3	0.044	N-1	0.044	V-6	0.038
Ch-4	0.044	N-3	0.047	V-7	0.031
Ch-6	0.045	N-6	0.053	V-8	0.031
Ch-7	0.050	N-7	0.048	V-9	0.040
Mean	0.046		0.048		0.035

Analytical Uncertainty $\pm$ .015

disposal site surface water tests presented in the hydro-geologic section (Table 6), wherein As and Cr values were virtually all below detectable limits. Therefore, the concentrations of the four trace metals in the surface water near the disposal site appear to be within the recommended EPA standards for protection of aquatic organisms.

It is generally difficult to identify a pollution source (i.e., food, seawater, and/or sediments) on the basis of field surveys because field studies cannot easily discriminate inputs from multiple sources; also, the differing ability to accumulate pollutants within a population (e.g., size, age, microhabitat) may obscure relationships between the source and body burden. Furthermore, accumulation may occur rapidly over brief periods such as storm events. These discrete episodes can be difficult to chacterize, but they are likely mechanisms at Vienna, as increased runoff from the disposal site and bankfull tributary erosion would suspend greater amounts of ash material in the runoff. However, the bioavailability of this material would be uncertain. Most investigations of metal uptake have found food and particulates to be a more important source of metals than water (Swartz and Lee, 1980).

The results of this study indicate that the dissolved metals in the surface water at the disposal site are probably not a source of contamination for the affected Fundulus population. This investigation revealed that the primary mechanism(s) of migration of heavy metals from the disposal site was through erosion and physical transport in the site tributaries to the surrounding environment. This process identifies the

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primary pathway of physical dispersal; however, the mecha-
nsim(s) by which metals are entering the Fundulus population
are unknown. The two primary routes for uptake of trace
metals by fishes are: 1) passive or active absorption
through the gills and 2) ingestion. Ingestion of contam-
inated food items is generally considered to be the major
source of trace elements accumulated in fishes (Dvorak et
al., 1978).

Evidence indicates that plants accumulate high concentrations
of pollutants which eventually become available to consumers
as particulate detritus or dissolved organic matter (Dvorak
et al., 1978). Benthic invertebrates are the principal con-
sumers of contaminated plant detritus. Although no com-
prehensive theory has adequately described trace metal cy-
cling through aquatic systems, largely due to the inherent
variability in the natural environment, the greatest bio-
accumulation/concentration factors generally are found among
sediment and detrital feeders. Trophic transfer of trace
metals to higher order consumers in aquatic systems gener-
ally results in lower trace-element concentrations in pred-
ators than in their prey (Dvorak et al., 1978). This lack
of obvious structure and unidirectional flow through the
food chain may limit, but does not preclude, biomagnifica-
tion. However, these differences among trace metals and
organisms in their potential for biomagnification may com-
plicate determination of how F. heteroclitus bioaccumulate
contaminants near the disposal site.

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SECTION VI

CONCLUSIONS

Having completed this problem definition phase of the study;
which included field reconnaissance, fall season sampling,
and limited ground water data and laboratory analyses; we
draw the following conclusions:

A.   Hydrogeological

1.   The fly ash deposit on the tidal marsh disposal
     site east of the Nanticoke River contains As, Cr,
     and Se.

2.   The shallow ground water system shows local contam-
     ination by sulfates, and a few detectable heavy
     metals slightly above PDWS.

3.   The local contamination in the shallow ground water sys-
     tem at the site has no significant effect on surface
     water quality leaving the site.

4.   The majority of the leachable components of the fly
     ash on the tidal marsh have apparently been leached
     away, and the fly ash now constitutes no significant
     threat to ground water quality.

5.   Unknown concentrations of sulfates and heavy metals
     may have leached into the ground water between the time
     of fly ash deposition and the present.

6. If contaminants reached the Pleistocene aquifer, they would probably discharge to the Nanticoke River and be diluted below detection limits.

7. The major avenue for migration of heavy metals leaving the site is via erosion and physical transport of the fly ash from the site drainageways to the moat and natural drainageways.

8. Indications are that the tidal marsh disposal site would pose no threat to ground water quality at a well which might be developed in the Pleistocene aquifer by the Town of Vienna, west of the river.

B. Biological

1. The organism which exhibited the greatest differences in concentration of the four trace metals among the three sampling locations was the mummichog, Fundulus heteroclitus. Mean trace metal concentrations were greater in disposal site specimens in all comparisons with the reference locations (Table 18) with five of the eight comparisons being statistically significant ($P < 0.05$). These results suggest that the Fundulus sampled at the disposal site and the Choptank site may be affected by localized sources of trace metal contamination. The Choptank site was later confirmed by the Maryland Department of Health as being affected by an unauthorized waste discharge.

Table 18

Summary of Wilcoxson's Test Results

Matrix	Vienna: Choptank				Vienna: Nanticoke			
	Al	As	Cr	Se	Al	As	Cr	Se
Mummichogs	N.S.[1]	*[2]	N.S.	N.S.	*	*	N.S.	*
	>[3]	>	>	>	>	>	>	>
Arrow-Arum								
Roots	N.S.	*	N.S.	*	N.S.	N.S.	N.S.	N.S.
	>	>	<	<	<	>	<	>
Fruits	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	>	>	?[4]	<	<	<	?	>
Sediment	*	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	<	>	<	$\geq$	=	>	<	$\leq$

[1]N.S. = not significant

[2] * = significant difference ($P < 0.05$)

[3]inequalities indicate which of the mean values was greater

[4] ? = all values were below detectable limits

2. Arrow-arum exhibited organ-specific bioconcentration for Al, As, and Cr. Root tissue levels of Al and As were significantly greater (P< 0.05) than in seeds for each location. Mean Cr levels were also substantially greater in the root tissue. Se levels exhibited no clear trend. Examination of concentration ratios between roots and seeds with metal concentrations in the associated sediment revealed similar evidence of organ-specific bioaccumulation.

3. Rhizome samples of Phragmites collected on the ash site exhibited relative metal concentrations similar to the top 15 cm of ash in which they had grown (i.e., Al> Cr> As> Se). This same elemental constituency is typical of endogenous soils and common in root tissue.

4. Analysis of sediment samples from the three locations showed only As to be consistently greater at the disposal site (Table 11) compared to the two reference locations. However, only one As comparison proved statistically significant (P < 0.05). The order of trace metal abundance in sediment was similar with fly ash results (i.e., Al> Cr> As> Se). However, statistical comparison of actual concentrations in sediment and fly ash from the disposal site revealed significant differences (P < 0.05) which suggest that the sediment samples collected near the disposal site were not predominantly fly ash.

5. Analysis of surface water indicated atypically high Se values in one set of samples. However, the laboratory technique used in preparing the samples is believed to

be the causative factor. All other metal concentrations were within recommended EPA guidelines for protection of aquatic organisms.

6. Comparisons of As levels in samples collected at the disposal site with those collected at the control locations revealed that the disposal site samples possessed greater As concentrations in seven of eight comparisons (Table 18). Furthermore, concentrations of As in mummichogs, arrow-arum roots and seeds, and sediment collected at the disposal site were significantly greater ($P < 0.05$) than As levels found in Choptank River collections (Table 18). Since the principal emission source of As in the U.S. is thought to be coal-fired power plants (Sittig, 1980), this element may prove to be the best "fingerprint" for identifying the potential environmental impact of the abandoned ash site.

SECTION VII

RECOMMENDATIONS

The above conclusions lead us to the following recommendations, which would best be implemented as a multi-phased program, each succeeding step dependent on the findings of the previous one. The biological and hydrogeological steps can be followed concurrently.

A. Hydrogeological

1. The amount of fly ash presently leaving the site via the surface drainageways should be determined to assess whether control measures are needed to prevent the re- lease of fly ash from the site.

2. The amount of fly ash in the shallow sediments of the moat and adjacent drainageways should be defined and the levels of heavy metals determined to assess whether or not sediment contamination is present, and whether or not remedial measures are needed.

B. Biological

1. Spring, summer, and fall sampling of mummichogs, from the disposal site and reference locations, to confirm tissue metal concentrations and determine food habits (potential metal sources).

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2. Sampling of predominant taxa of food organisms of mummi-
    chogs to determine concentrations of metals and their
    potential as a source of contamination.

3. Further sampling of stream sediments and/or suspended
    particulates in the surface waters to determine heavy
    metal content and their role as potential sources of
    contamination.

4. Research possible higher and/or lower pathways among
    trophic levels to further clarify the impact of the
    Vienna site on area biota and to what level toxicity
    may be a significant concern to organisms on or off
    the site.

SECTION VIII

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SECTION IX

APPENDICES

APPENDIX A

CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS
OF THE VIENNA MARSHES

APPENDIX A

CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS
OF THE VIENNA MARSHES

1) System   Estuarine
     Subsystem   Intertidal
       Class   Unconsolidated Shore (clams)
         Subclass   Mud and Nonpersistent
           Water Regime   Regularly Flooded
             Water Chemistry Mixohaline
               Soil   Mineral

2) System   Estuarine
     Subsystem   Intertidal
       Class   Emergent Wetland (arrow-arum)
         Subclass   Nonpersistent
           Water Regime   Regularly Flooded
             Water Chemistry Mixohaline
               Soil   Mineral

3) System   Estuarine
     Subsystem   Intertidal
       Class   Emergent Wetland (Phragmites, Big Cordgrass -
                                               dominant)

                                             (Saltmeadow Cordgrass - subdom.)
         Subclass   Persistent
           Water Regime   Irregularly Flooded and Regularly Flooded
             Water Chemistry Mixohaline
               Soil   Mineral

4) System   Estuarine
     Subsystem   Intertidal
       Class   Scrub-Shrub Wetland (Baccharis, Dogwood)
         Subclass   Broad-leaved Deciduous
           Water Regime   Irregularly Flooded
             Water Chemistry Fresh to Mixohaline
               Soil   Mineral

APPENDIX A

CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS
OF THE VIENNA MARSHES
(cont'd)

5) System   Riverine
       Subsystem   Tidal
          Class   Streambed
            Subclass   Mud and (Sand)
              Water Regime   Regularly Flooded
              Water Chemistry   Mixohaline to Fresh
                 Soil   Mineral

6) System   Riverine
       Subsystem   Tidal
          Class   Unconsolidated Shore and Emergent Wetland
                                                          (arrow-arum)

            Subclass   Mud and Nonpersistent
              Water Regime   Regularly Flooded
              Water Chemistry   Fresh to Mixohaline
                 Soil   Mineral

According to: Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe.
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APPENDIX B

PROBABLE AMPHIBIANS AND REPTILES
IN THE VIENNA AREA

APPENDIX B

PROBABLE AMPHIBIANS AND REPTILES
IN THE VIENNA AREA

	General Habitat	
Species*	Marsh- Wetlands	Uplands**
Eastern Tiger Salamander Ambystoma tigrinum		X
Northern Dusky Salamander Desmognathus fuscus		X
Red-backed Salamander Plethodon cinereus		X
Eastern Mud Salamander Pseudotriton montanus		X
Northern Two-lined Salamander Eurycea bislineata		X
Eastern Spadefoot Toad Scaphiopus holbrooki		X
Bullfrog Rana catesbeiana	X	
Green Frog Rana clamitans	X	
Southern Leopard Frog Rana sphenocephala	X	
Wood Frog Rana sylvatica	X	X
Eastern Narrow-mouthed Toad Gastrophryne carolinesis	X	X
American Toad Bufo americanus	X	X
Fowler's Toad Bufo fowleri	X	X
Green Tree Frog Hyla cinera	X	X

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APPENDIX B
(continued)

	General Habitat	
Species*	Marsh-Wetlands	Uplands**
Northern Spring Peeper Hyla crucifer	X	X
Northern Cricket Frog Acris crepitans	X	
New Jersey Chorus Frog Pseudacris triseriata	X	X
Common Snapping Turtle Chelydra serpentina	X	
Eastern Mud Turtle Kinosternon subrubrum	X	
Spotted Turtle Clemmys guttata	X	
Eastern Bog Turtle Terrapene carolina		X
Eastern Painted Turtle Chrysemys picta	X	
Red-bellied Turtle Chrysemys rubriventris	X	
Northern Fence Lizzard Sceloporus undulatus		X
Five-lined Skink Eumeces faciatus		X
Broad-headed Skink Eumeces laticeps		X
Ground Skink Lygosoma laterale		X
Northern Water Snake Natrix sipedon	X	

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APPENDIX B
(continued)

Species*	General Habitat	
	Marsh-Wetlands	Uplands**
Eastern Ribbon Snake Thamnophis sauritus	X	
Eastern Garter Snake Thamnophis sirtalis	X	
Northern Brown Snake Storeria dekayi		X
Northern Red-bellied Snake Storeria occipitomaculata		X
Eastern Hog-nosed Snake Heterodon platyrhinos		X
Southern Ring-necked Snake Diadophis punctatus		X
Eastern Worm Snake Carphophis amoenus		X
Northern Black Snake Caluber constrictor	X	
Rough Green Snake Opheodrys aestivus	X	X
Corn Snake Elaphe guttata		X
Black Rat Snake Elaphe obsoleta		X
Eastern King Snake Lampropeltis getulus	X	X

APPENDIX B
(continued)

	General Habitat	
Species*	Marsh-Wetlands	Uplands**
Coastal Plain Milk Snake Lampropeltis triangulium		X
Southeastern Scarlet Snake Coccinea spp.		X
Northern Copperhead Agkistrodon contartrix		X

Sources: Conant, R. 1958. A Field Guide to Reptiles and
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entific Report No. 65, Gloucester Point, Virginia.

 * Subspecies nomenclature omitted.

** Includes moist and/or aquatic upland habitats, such as
springs and small streams.

APPENDIX C

PROBABLE MAMMALS OF THE VIENNA AREA

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APPENDIX C

PROBABLE MAMMALS OF THE VIENNA AREA

Species	General Habitat	
	Marsh-Wetlands	Uplands
Opossum Didelphis marsupialis	X	X
Least Shrew Cryptotis paroa	X	
Shorttail Shrew Blarina brevicauda	X	X
Eastern Mole Scalopus aquaticus		X
Little Brown Myotis Myotis lucifugus		X
Eastern Pipistrel Pipistrellus subflavus		X
Red Bat Lasiurus borealis		X
Big Brown Bat Eptesicus fuscus		X
Raccoon Procyon lotor	X	X
Mink Mustela vison	X	
River Otter Lutra canadensis	X	
Striped Skunk Mephitis mephitis	X	X
Red Fox Vulpes fulva	X	X
Gray Fox Urocyon cinereoargenteus		X
Woodchuck Marmota monax		X

Source: Paradisco, J.L. 1969. "Mammals of Maryland." U.S.D.I.,
        Bureau of Sport Fisheries and Wildlife. North American
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APPENDIX D

BORING LOGS

Project <u>Maryland PPSP</u>   Owner _____

Location <u>Vienna, Maryland</u>   W.O. Number _____

Well Number <u>V-20</u>   Total Depth <u>16.5 ft.</u>   Diameter <u>3.5 in.</u>

Surface Elevation _____ Water Level: Initial <u>5 in.</u>   24-hrs. _____

Screen: Dia. _____ Length _____ Slot Size _____

Casing: Dia. _____ Length _____ Type _____

Drilling Company _____ Drilling Method <u>Hand Auger</u>

Driller _____ Log By <u>M. Hewitt</u>   Date Drilled <u>12/10/81</u>

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
1				Dark brown silt and dark gray to black fine fly ash.
2				
3				Organic root and vegetal mat in dark brown clayey silt matrix. Plant remains graded in and out, with runny silts.
4				
5				
6				
7				
8				
9				Dark brown very runny silt.
10				
11				
12				
13				

D-1

Environmental Resources Management

Drilling Log

Project **Maryland PPSP**   Owner_____

Location **Vienna, Maryland**   W.O. Number_____

Well Number **V-1**   Total Depth **19 ft.**   Diameter **3.5 in.**

Surface Elevation_____ Water Level: Initial_____ 24-hrs. **2.25 in.**

Screen: Dia._____ Length_____ Slot Size_____

Casing: Dia._____ Length_____ Type_____

Drilling Company_____ Drilling Method **Hand Auger**

Driller_____ Log By **M. Hewitt** Date Drilled **11/17/81**

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
1–3				Dark gray to black fine fly ash, with roots and dark brown silt from 34-38 inches.
4–7				Organic root and vegetal mat in dark brown clayey silt to silty clay matrix. Plant remains grade in and out, with runny silts.
8–9				Dark brown very plastic clay with trace silt.
10–13				Alternating dark brown very runny silts and clayey silts to silty plastic clays.

D-2

Project __Maryland PPSP__ _____ Owner _____

Location __Vienna, Maryland__ _____ W.O. Number _____

Well Number __V-7__ _____ Total Depth __7 ft.__ Diameter __3.5 in.__

Surface Elevation _____ Water Level: Initial __5 in.__ 24-hrs. _____

Screen: Dia. _____ Length _____ Slot Size _____

Casing: Dia. _____ Length _____ Type _____

Drilling Company _____ Drilling Method _____

Driller _____ Log By _____ Date Drilled _____

Sketch Map
Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
1				Organic root and vegetal mat in dark brown silt matrix, with some fly ash.
2				Dark brown silt and fly ash, with some roots.
3				Dark brown silt and roots with some fly ash.
4				Organic root and vegetal mat with dark brown clayey silt matrix.
5				
6				
7				Dark brown very runny silt.

D-3

Project **Maryland PPSP** _____ Owner _____

Location **Vienna, Maryland** _____ W.O. Number _____

Well Number **V-4** _____ Total Depth **7.5 ft.** _____ Diameter _____

Surface Elevation _____ Water Level: Initial **1.5 in.** 24-hrs. _____

Screen: Dia. _____ Length _____ Slot Size _____

Casing: Dia. _____ Length _____ Type _____

Drilling Company _____ Drilling Method **Hand Auger** _____

Driller _____ Log By **M. Hewitt** _____ Date Drilled **11/19/81**

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
1 2 3 4 5 6 7 8				Two-inch root mat underlain by dark gray to black fine fly ash. Organic root and vegetal mat in dark brown silty clay to clayey silt matrix.

D-4

Project **Maryland PPSP** Owner_____

Location **Vienna, Maryland** W.O. Number_____

Well Number **V-3** Total Depth **28 in.** Diameter **3.5 in.**

Surface Elevation_____ Water Level: Initial **7 in.** 24-hrs._____

Screen: Dia._____ Length_____ Slot Size_____

Casing: Dia._____ Length_____ Type_____

Drilling Company_____ Drilling Method **Hand Auger**

Driller_____ Log By **M. Hewitt** Date Drilled **11/19/81**

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
1 2 3				Two-inch root mat, underlain by dark gray to black fine fly ash.

Organic root and vegetal mat in dark brown clayey silt matrix. |

D-5

Project __Maryland PPSP__ Owner_____

Location __Vienna, Maryland__ W.O. Number_____

Well Number __V-2__ Total Depth __32 in.__ Diameter __3.5 in.__

Surface Elevation_____ Water Level: Initial __13 in.__ 24-hrs_____

Screen: Dia._____ .Length_____ Slot Size_____

Casing: Dia._____ Length_____ Type_____

Drilling Company_____ Drilling Method __Hand Auger__

Driller_____ Log By __M. Hewitt__ Date Drilled __11/19/81__

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
1 2 3				Two-inch root mat, underlain by dark gray to black fine fly ash. Organic root and vegetal mat, in dark brown clayey silt matrix. Dark brown very runny silt.

Project __Maryland PPSP_____ Owner_____

Location __Vienna, Maryland_____ W.O. Number_____

Well Number _____V-1_____ Total Depth_____ Diameter_____

Surface Elevation_____ Water Level: Initial_____ 24-hrs._____

Screen: Dia._____ Length_____ Slot Size_____

Casing. Dia._____ Length_____ Type_____

Drilling Company_____ Drilling Method_____

Driller_____ Log By_____ Date Drilled_____

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
-14				
-15				
-16				
-17				Dark brown very runny silt.
-18				
-19				Silty fine white quartz sand, well sorted.

D-7

Drilling Log

Project _Maryland PPSP_	Owner _____
Location _Vienna, Maryland_	W.O. Number _____
Well Number _V-20_ Total Depth _____	Diameter _____
Surface Elevation _____ Water Level: Initial _____	24-hrs. _____
Screen: Dia. _____ Length _____	Slot Size _____
Casing: Dia. _____ Length _____	Type _____
Drilling Company _____ Drilling Method _____	
Driller _____ Log By _____	Date Drilled _____

Sketch Map

Notes

Depth (Feet)	Graphic Log	Well Construction	Sample Number	Description/Soil Classification (Color, Texture, Structures)
14				
15				
16				Very silty medium to coarse grained poorly sorted quartz sand; subangular; silt fraction grades out within 2 feet. Some fine non-quartz gravel.
17				

Environmental Resources Management, Inc.

APPENDIX E

SUMMARY OF t-TEST RESULTS

APPENDIX E

SUMMARY OF t-TEST RESULTS

Matrix	Vienna: Choptank				Vienna: Nanticoke			
	Al	As	Cr	Se	Al	As	Cr	Se
Mummichogs	N.S.[1] >[3]	*[2] >	N.S. >	N.S. >	* >	* >	* >	* >
Arrow-Arum Roots	N.S. >	* >	N.S. <	* <	N.S. <	N.S. >	N.S. <	N.S. >
Fruits	N.S. >	* >	N.S. ?[4]	N.S. <	N.S. <	N.S. <	N.S. ?	N.S. >
Sediment	* <	* >	N.S. <	N.S. $\geq$	N.S. =	N.S. >	N.S. <	N.S. $\leq$

[1]N.S. = not significant

[2]* = significant difference ($P < 0.05$)

[3]inequalities indicate which of the mean values was greater

[4]? = all values were below detectable limits